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LIFE HISTORY OF PLUTELLA MACULIPENNIS, THE DIAMOND-BACK MOTH

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INTRODUCTION

In the Arkansas Valley of Colorado cabbage is grown on a moderate scale, chiefly for local consumption. As is usual with this crop, it is the host of numerous insect enemies, among which is the larva of the diamond-back moth (*Plutella maculipennis* Curtis [1]).

The writer has had the diamond-back moth under observation since 1908, and particularly since 1914. Throughout this period, except from the latter part of December, 1914, until early in March, 1915, when work was carried on at Phoenix, Ariz., all life-history observations were made at Rocky Ford, Colo.

DESCRIPTION OF THE DIAMOND-BACK MOTH

THE MOTH

The adult (Pl. 1, *A*) is a slender moth, grayish or brownish in general color, with ocherous markings on head, thorax, and wings. The female is usually lighter in color than the male. The wing expanse is about five-eighths of an inch, and, when at rest, the wings are folded close to the body. Flight is rather feeble and cautious, the moth usually coming to rest among the leaves of cruciferous vegetables or about cruciferous weeds. The nectar of such plants is the natural food of the adults, although in captivity they feed readily on diluted honey.

THE EGG

The egg is minute, scalelike, greenish white or yellowish in color, and is deposited singly, or rarely in groups of two or three, on the lower side of the leaves of cruciferous plants. In cool weather eggs of the first and last broods may be deposited on the upper side of the leaves, but this is apparently abnormal.

[1] Order Lepidoptera, family Yponomeutidae.

THE LARVA

The newly hatched larva is a minute, light-colored creature with a dark head. The mature larva (Pl. 1, *B*) is about three-tenths of an inch in length, slender, fusiform in shape, and dull green in color. The head is light colored and marked with brownish spots or lines.

In habit the larva is irritable, and, when disturbed, wriggles about actively. When feeding on tender-leaved plants (Pl. 1, *D*), the larva cuts entirely through the leaf, but with plants like cabbage, having thick leaves, it removes irregular areas of the lower surface without cutting through the upper epidermis. During cool weather the larvæ burrow into the leaves immediately after hatching, and for the following two to four days live in irregular blotch mines, which they form between the upper and lower epidermis.

THE PUPA

The pupa (Pl. 1, *C*) is slender, yellowish or whitish in color, and often striped with brown. It is about one-fourth of an inch in length and is inclosed in a beautiful, delicate, lacelike cocoon of white or grayish silken threads, attached to the leaves of the food plant, often along the midrib. In cool weather larvæ occasionally pupate in cracks in the soil about the base of the host plant.

DISTRIBUTION OF THE MOTH

The diamond-back moth is a cosmopolitan species which in the United States apparently occurs wherever cabbage (*Brassica oleracea capitata*) is grown.

In September and October, 1908, the several stages were noted by the writer on cabbage and turnip (*Brassica rapa*) at Santa Ana, Orange, Tustin, Garden Grove, Whittier, and Watts, Cal. From January to June, 1909, the larvæ were noted on cruciferous vegetables at Brownsville, Tex., and other localities in the lower Rio Grande Valley. In July and August, 1909, larvæ were noted on cabbage at Houston, Dallas, and Amarillo, Tex., and at Rocky Ford and Greeley, Colo. In December, 1909, and January, 1910, larvæ were found on cabbage and turnip at Lake Charles and Lake Arthur, La., and at Beaumont, Corpus Christi, San Antonio, Sabinal, and Laredo, Tex. From July, 1910, until February, 1911, larvæ were frequently found on cabbage, turnip, and watercress (*Radicula sinuata*) at Honolulu and Wahiawa, Oahu, Hawaiian Islands. At Honolulu the species was kept under fairly close observation, and it was noted that the larvæ did not become sufficiently numerous at any time to cause appreciable damage. During February and March, 1913, larvæ were noted on cabbage at Thermal, Coachella, Calexico, and El Centro, Cal. In May and June, 1913, larvæ were found on cabbage at Marion, N. C., and at Chester, N. J. All stages of this insect were found on various cruciferous plants at Phoenix, Glendale, Tempe, and other points in the Salt River Valley of Arizona during January and

February, 1915. In August, 1916, larvæ were noted on cabbage and turnip at Maxwell and French, N. Mex.

FOOD PLANTS

The larva of the diamond-back moth appears to feed exclusively on cruciferous plants. The writer has observed it feeding on the following cultivated varieties: Cabbage, cauliflower (*Brassica oleracea botrytis*), turnip, radish (*Raphanus sativus*), rape (*Brassica napus*), kale (*Brassica oleracea acephala*), mustard (*Brassica nigra*), "Chinese mustard" (*Brassica juncea*), kohlrabi (*Brassica oleracea caulo-rapa*), watercress (*Radicula sinuata*), horse-radish (*Radicula armoracea*), sweet alyssum (*Koniga maritima*), and candytuft (*Iberis amara*). While cabbage is decidedly the favorite, rape, cauliflower, turnip, and mustard are readily eaten.

Among weeds the writer noted the larvæ on only two species: Wild watercress (*Roripa sinuata*) and hedge mustard (*Sisymbrium* sp.), both being plants with mustard-like characteristics. Although the larvæ feed on the foliage of these weeds, they prefer the blossom buds or the blossoms, and are much more likely to be found among these than on the leaves. The watercress occurs in abundance along fences and irrigation laterals in the Arkansas Valley. It blossoms from early spring until late summer and supplies readily available food for the moths and larvæ. The hedge mustard, tentatively identified by Prof. J. J. Thornber, of the Arizona Experiment Station, as *Sisymbrium irio*, is a common weed in the irrigated sections of southern Arizona and blossoms throughout the winter.

SEASONAL HISTORY

At Rocky Ford, Colo., seven generations of the diamond-back moth occur annually. The winter is passed in the adult or moth stage. Moths which develop during October and November find shelter throughout the winter among the leaves of cabbage plants and other crop remnants left standing in the field.

In the spring following a dry "open" winter the moths are noticeably less numerous than after a winter of heavy snows; hence, it would appear that snow serves as an additional protection for the hibernating adults. Although larvæ and pupæ occur in small numbers in the field during November and occasionally in early December, they do not survive the winter. The writer repeatedly experimented with larvæ and pupæ, both indoors and out, to determine their resistance to cold, and in every case all died during the late fall or early winter. The most painstaking examination during the spring months failed to reveal a single living larva or pupa on cabbage or other plants standing in the field or stored in cellars or pits.

On the other hand, the writer found living moths in the field at Rocky Ford throughout the entire winter. They usually hibernate among the dead or drooping leaves of cabbage plants, crawling between the leaves, with the advent of the first severe frosts, where they remain concealed

until the following spring. Usually the moths remain motionless, although on exceptionally warm winter days they may fly a little if disturbed.

The moths emerge from hibernation early in May and fly to the blossoms of cruciferous plants, usually the wild watercress (*Roripa sinuata*), to feed. In 1914, 1915, and 1916 the overwintered moths were first noted on the wing on May 4, 3, and 1, respectively. Copulation takes place shortly after the moths begin to fly, and oviposition commences within a day or two, the eggs of the overwintered females usually being deposited on the watercress. Occasionally the foliage of turnips which have been protected throughout the winter by snow or stored in pits is available for this purpose. Reproduction continues throughout the summer and until the severe freezes of late fall kill off the last belated larvæ and pupæ. In the Arkansas Valley the larvæ are most numerous in June or early July, the later generations being greatly reduced by parasites. The moths are most numerous during the fall, when they frequently occur in considerable numbers about cabbage and other cruciferous vegetables.

At Rocky Ford the egg stage covered from 3 to 6 days, the larva stage from 9 to 28 days, and the pupa stage from 5 to 13 days, the life cycle from egg to adult thus occupying from 17 to 47 days.

In the South the diamond-back moth is active throughout the year, and the larvæ are to be found at all seasons.

LIFE HISTORY OF THE MOTH

The principal life-history studies of the diamond-back moth were carried out at Rocky Ford, Colo., from 1914 to 1916. The insects were confined in battery-jar cages under open-air conditions. The moths were fed with the blossoms (nectar) of cruciferous plants or with diluted honey, and the larvæ were reared on cabbage or turnip foliage.

On May 4, 1914, several overwintered moths which had just issued from hibernation were captured in the field and confined in a cage. Their record is given in Table I.

TABLE I.—*Record of the generations of Plutella maculipennis at Rocky Ford, Colo., in 1914*

Item.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.
Moths captured and confined	May 4	.....	.....	.....	.....	.....	.....
First adults issued	.....	June 1	June 19	July 7	July 25	Aug. 13	Sept. 7
First eggs deposited	May 6	June 2	June 20	July 8	July 26	Aug. 14	Sept. 8
First eggs hatched	May 11	June 6	June 23	July 11	July 29	Aug. 17	Sept. 12
First cocoons formed	May 23	June 13	July 1	July 20	Aug. 7	Aug. 31	Sept. 23
First larvæ pupated	May 24	June 14	July 2	July 21	Aug. 8	Sept. 2	Sept. 25
First adults issued	June 1	June 19	July 7	July 25	Aug. 13	Sept. 7	Oct. 3
Egg stage.....days	5	4	3	3	3	3	4
Larval stage.....do	13	8	9	10	10	16	13
Pupal stage.....do	7	5	5	4	5	5	8
Total duration.....do	25	17	17	17	18	24	25

The moths of the seventh generation, which issued on October 3 and 4, 30 in number, remained in the cage in which they were reared until November 9. They fed on diluted honey, but deposited no eggs. On November 9 they were transferred to a cage containing a dead cabbage plant and 2 inches of moistened soil and placed in the laboratory cellar. They crawled in among the dead leaves or clung to the underside of the cloth cover of the cage, becoming semidormant throughout the winter. From December, 1914, until March, 1915, during the writer's absence, the cage was neglected and the soil became dry, which was apparently detrimental to the moths, as several died.

On April 5, 1915, the cage was taken from the laboratory cellar and placed in a slightly heated room in the laboratory. Six moths were alive and apparently in good condition. They remained partially dormant until April 30, when they became active and began to feed. On May 2 the first eggs were deposited and others were deposited at intervals until May 14. Illness at this time occasioned the loss of these eggs.

REARING RECORDS FOR 1915–16

On August 18, 1915, life-history studies were resumed with fresh material collected in the field. Merely for the sake of convenience the first brood reared from this material will be arbitrarily designated the "first generation," although in reality it is the sixth generation which developed in 1915. The records of the seven generations of 1915–16 are given in Table II.

TABLE II.—*Record of the generations of Plutella maculipennis at Rocky Ford, Colo., in 1915–16*

Item.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.
Adults issued and confined	1915 Aug. 18	1915	1915	1916	1916	1916	1916 .....
First adults issued	.....	Sept. 12	[a]Nov. 2	June 1	June 29	July 18	Aug. 5
Adults mated	.....	.....	1916. May 3	.....	.....	.....	.....
First eggs deposited	Aug. 19	Sept. 16	May 4	June 10	July 1	July 20	Aug. 6
First eggs hatched	Aug. 23	Sept. 22	May 8	June 14	July 4	July 23	Aug. 10
First cocoons formed	Sept. 4	Oct. 18	May 25	June 24	July 12	July 31	Aug. 22
First larvæ pupated	Sept. 5	Oct. 20	May 26	June 25	July 13	Aug. 1	Aug. 24
First adults issued	Sept. 12	Nov. 2	June 1	June 29	July 18	Aug. 5	Aug. 30
Egg stage.....days..	4	6	4	4	3	3	4
Larval stage.....do....	13	28	18	11	9	9	14
Pupal stage.....do....	7	13	6	4	5	4	6
Total duration.....do....	24	47	28	19	17	16	24

[a] Or Nov. 3.

Fifty-two adults, about equally divided as to sex, developed on November 2 and 3. These moths were confined in battery jars containing moistened earth and dead cabbage plants, and on November 10 were placed in the laboratory cellar. Throughout the winter the cages were examined and the soil moistened at frequent intervals. On May 2,

1916, the cages were taken from the cellar and placed in the open-air rearing shelter. Thirty moths were alive at this date. It was noted that many more males than females died during the winter. The moths fed eagerly on diluted honey. On May 3 one pair mated and was isolated in another cage. The record for this pair is given in Table II (third generation).

The experiment with this material, having been carried a full year, was discontinued on August 30, 1916. For some unknown reason the moths which issued on June 1 deposited no eggs until June 10, and this largely accounts for the overlapping (August 19 to 30, 1916) of the life cycle.

During 1916 the preceding life-history studies were verified by a duplicate set of rearing experiments. The records are essentially the same as those given in Table II, and the details will therefore be omitted.

On May 3, 1916, a male and two females which had just issued from winter quarters were captured about the blossoms of watercress and confined in a cage. On May 4 the male mated with one of the females, and the first eggs, 50 in number, were deposited on this day. On May 5, 61 eggs were deposited. The first eggs hatched on May 7, and from this material the species was reared throughout the season. The dates on which the adults of the seven successive generations issued are given in Table III.

TABLE III.—*Date of issue of adults of seven generations of Plutella maculipennis at Rocky Ford, Colo., 1916*

May 31	Adults of first generation issued.
June 27	Adults of second generation issued.
July 16	Adults of third generation issued.
Aug. 4	Adults of fourth generation issued.
Aug. 25	Adults of fifth generation issued.
Sept. 22	Adults of sixth generation issued.
Nov. 6	Adults of seventh generation issued.

The adults of the seventh generation were confined in the usual way and placed in the laboratory cellar on November 10, 1916. At the time this article was written, late in December, 1916, these moths were hibernating in excellent condition.

REARING RECORDS AT PHOENIX, ARIZ.

In addition to the life-history studies carried on at Rocky Ford, Colo., the writer reared the diamond-back moth through one generation at Phoenix, Ariz. There the cages were kept in an open, unheated hallway where the temperature varied little from that prevailing out of doors.

On December 30, 1914, a few nearly mature larvæ were collected from turnips in a garden at Phoenix and confined. The first cocoons were formed on January 2, 1915, and the first larvæ pupated on January 3. The first adults, three in number, issued on January 20 and 21. These moths were isolated in another cage. The record is given in Table IV.

TABLE IV.—*Rearing records of Plutella maculipennis at Phoenix, Ariz., in 1914*

Jan. 20–21	First adults issued.
Jan. 23	First eggs deposited.
Feb. 5	First eggs hatched.
Feb. 17	First cocoons formed.
Feb. 19	First larvæ pupated.
Mar. 2	First adults issued.

As noted in Table IV the stages are as follows:

	Days.
Egg stage	13
Larva stage	14
Pupa stage	11
Total duration	38

The larvæ reared at Rocky Ford during May lived as leaf-miners for the first two or three days of their existence, whereas those reared at Phoenix during February lived in mines for four days. At Rocky Ford during October and at Phoenix during January and February many of the older larvæ changed to a dark, dull-green color and were marked with reddish spots. The mining habit and the changes in coloration occurred with larvæ in the field as well as those confined in cages and were obviously induced by low temperature.

EGG-LAYING RECORDS

Egg-laying records were obtained at Rocky Ford by confining single pairs of moths, immediately after they issued, in large jelly glasses. The moths were fed diluted honey or the nectar of watercress. A cabbage leaf was placed in each cage daily, and upon these leaves the eggs were deposited. The eggs were counted daily and destroyed. The number of eggs deposited by nine females which issued during July and August were 287, 116, 413, 202, 237, 427, 282, 168, and 451, respectively, or an average of 287 eggs per female.

A detailed record of the female of one of these pairs of moths, which issued on August 16, is given in Table V.

TABLE V.—*Egg-laying record of a single female of Plutella maculipennis at Rocky Ford, Colo., in 1916*

	Eggs deposited.
Aug. 17	26
Aug. 18	78
Aug. 19	69
Aug. 20	43
Aug. 21	32
Aug. 22	23
Aug. 23	11
Total	282

Both moths died on August 23, having lived 7 days. In the cooler weather of spring and fall the life of the moths and the egg-laying period are lengthened and may cover from 10 to 14 days.

NATURAL ENEMIES [1]

The diamond-back moth is a striking example of a potentially serious pest normally held in repression by parasites. The most effective species engaged in this beneficial work is an ichneumonid, *Angitia plutellae* Vier. (Pl. 2, *A*). The writer reared this parasite from larvæ of the diamond-back moth collected at various points in the Arkansas Valley, at Colorado Springs, Colo., and at Phoenix, Ariz. In Colorado it is active whenever Plutella larvæ are in evidence. In Arizona it appears to work throughout the year. With the later generations of the diamond-back moth it is not unusual to find from 50 to 70 per cent of the larvæ infested by this parasite.

Parasitized larvæ of *P. maculipennis* reach maturity and form their cocoons. The larvæ of *Angitia plutellae*, one from each infested Plutella larva, issue and spin compact gray cocoons within the Plutella cocoons. Unfortunately the larvæ of *A. plutellae* are occasionally infested by a chalcidid hyperparasite, *Spilochalcis delira* Cresson (Pl. 2, *B*). The writer had *A. plutellae* under observation at Rocky Ford during the years 1911 to 1916, and at no time during this period was the hyperparasite sufficiently numerous to reduce noticeably the numbers of its host.

Other parasites reared by the writer at Rocky Ford from the larvæ of the diamond-back moth were identified as *Meteorus* sp. and *Mesochorus* sp., and a new species of Microplitis. These parasites were, however, too rare to be of noticeable benefit in reducing the numbers of the larvæ of *P. maculipennis*.

No parasites were reared by the writer from the eggs or pupæ of the diamond-back moth, and no predacious or fungus enemies have been observed.

EXTENT OF INJURY

Although the larvæ of the diamond-back moth feed on many cruciferous plants, they seldom cause appreciable damage to any except cabbage, cauliflower, and rape. In Colorado the larvæ are usually sufficiently numerous on these plants during June or early July to riddle the leaves badly. The later generations are so effectively held in check by parasites that little or no damage results. Whenever damage occurs, it is always most serious with young plants. Sometimes the larvæ crawl in among the leaves of newly transplanted cabbage and feed on the tender leaves at the center. In such cases the heads, if any develop, are usually deformed and worthless.

[1] The ichneumonids were identified by Mr. A. B. Gahan, of the Bureau of Entomology, and the chalcidid by Mr. J. C. Crawford, of the United States National Museum.

CONTROL MEASURES

During the years 1909–1916 the writer made many insecticide experiments to determine the best means of controlling the various "worms," including the larvæ of the diamond-back moth, which infest cabbage and related vegetables. Tests were made with Paris green, arsenate of lead, zinc arsenite, nicotine sulphate, and soap solutions. In the writer's experience the following mixture, applied as a spray, is unquestionably the most effective remedy against the larvæ of the diamond-back moth on cabbage.

Paris green	pounds	2
Soap	do	6
Water	gallons	100

In small plantings this mixture may be applied with a portable compressed-air knapsack sprayer, fitted with an extension rod, elbow, and a nozzle of the disk or Vermorel type having a fine aperture. The application should be thorough, and, as an adhesive is required, owing to the waxy "bloom" of the leaves, common laundry soap will be found satisfactory and is always cheap and available.

Powdered arsenate of lead, applied at the rate of 4 pounds in 100 gallons of water, is another effective remedy for worms on cabbage and at present, owing to the abnormal conditions brought about by the war in Europe, is cheaper than Paris green.

Unfortunately considerable prejudice exists against the use of arsenicals on cabbage. This feeling is groundless and should be discouraged.

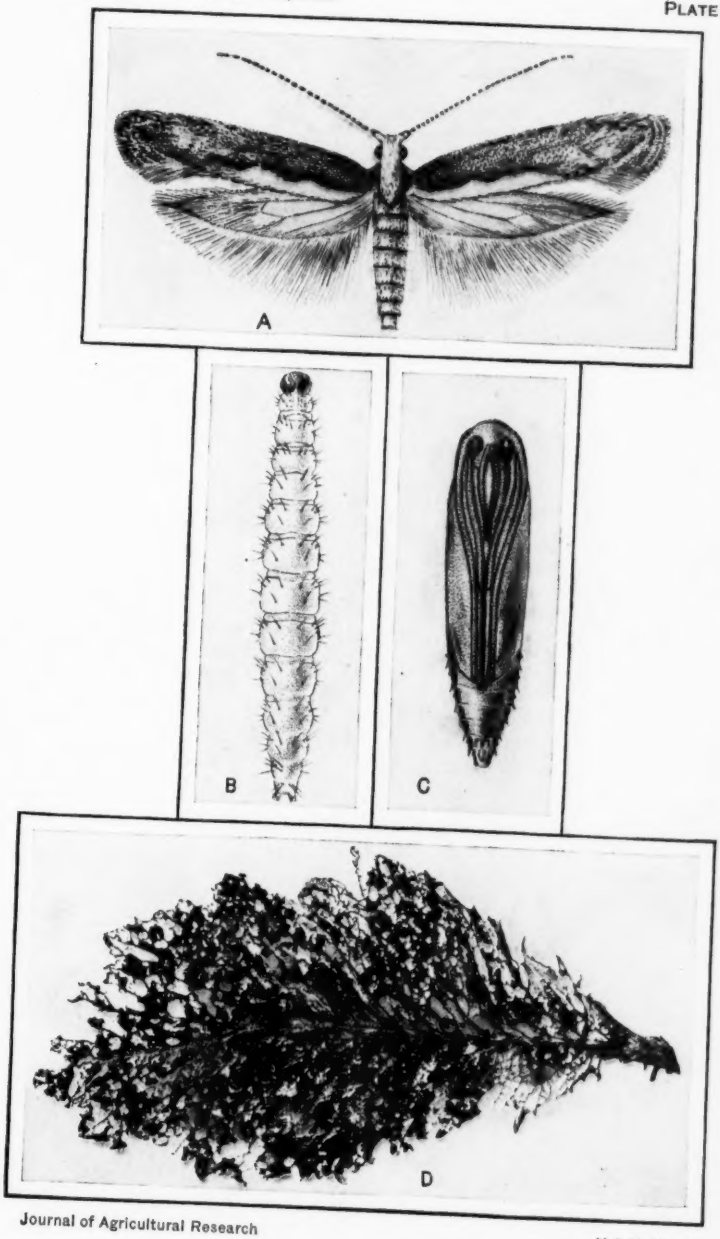
CONCLUSION

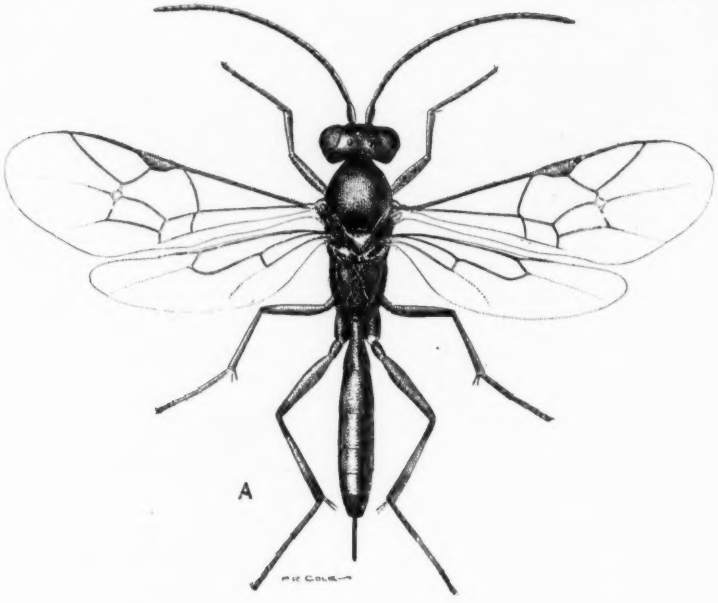
The diamond-back moth (*Plutella maculipennis*) is a cosmopolitan species widely distributed in the United States. The larvæ are slender, green "worms" which infest many varieties of cruciferous plants but seldom cause appreciable injury to any except cabbage, cauliflower, and rape. At Rocky Ford, Colo., seven generations, or broods, develop annually. The life cycle from egg to adult is passed in from 16 to 47 days. In the Southern States this insect is active throughout the year.

Although it develops with remarkable rapidity and is capable of causing extensive damage if unchecked, the diamond-back moth is so effectively held in repression by parasites that it rarely becomes more than a minor pest. Whenever the parasites are inactive and the larvæ become sufficiently numerous to demand attention, they may be readily controlled by spraying the infested plants with an arsenical.

PLATE 1

A.—*Plutella maculipennis:* Adult. Much enlarged. Original.
B.—*Plutella maculipennis:* Larva. Enlarged. Original.
C.—*Plutella maculipennis:* Pupa. Enlarged. Original.
D.—Leaf of mustard, showing injury by *Plutella maculipennis*. From Jones.


A
B
C
D


A

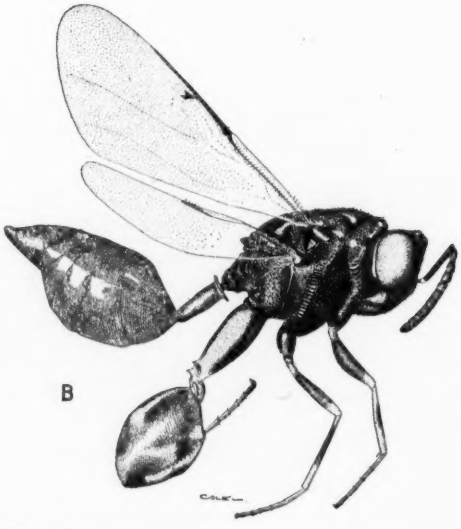

B

PLATE 2

A.—*Angitia plutellae*, parasite of *Plutella maculipennis*. Original.

B.—*Spilochalcis delira*, a parasite on *Angitia plutellae*, and therefore a secondary or injurious parasite. Highly magnified. Original.

DAILY VARIATION OF WATER AND DRY MATTER IN THE LEAVES OF CORN AND THE SORGHUMS

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INTRODUCTION

In connection with the study of the water relations of corn and the nonsaccharin sorghums previously reported by the writer,[2] it was thought advisable to determine the daily variation of the water and dry matter in the leaves of these plants. A knowledge of the variation of the water in the leaves should throw some light on the relative ability of these plants to absorb water from the soil and to transport it to regions of loss from transpiration, while a study of the daily variation of dry matter in the leaves would permit a comparison of the relative power of the plants to manufacture food under different climatic conditions. The experiments herein reported were conducted during the summers of 1914, 1915, and 1916 at the State branch Experiment Station at Garden City, Kans.

EXPERIMENTAL METHODS

CULTURAL METHODS

The plants used in these experiments were Pride of Saline corn (*Zea mays*), Blackhull kafir (*Andropogon sorghum*), and Dwarf milo (*A. sorghum*). In 1914 and 1915 the plants were grown in alternate rows on the same plot, while in 1916 the experiments were made with plants grown on a series of one-twentieth-acre plots. The plants were grown in a sandy-loam soil that had been fall-plowed and irrigated with approximately 8 inches of water. The crops were surface-planted in rows 44 inches apart. After the plants were a few inches high the corn was thinned to a distance of 2 feet between the plants, Blackhull kafir to 1½ feet, and the Dwarf milo to 1 foot. The plots were scraped with a hoe to keep the weeds down, but no other cultivation was given during the growing season. They received no water after the fall irrigation, except that which came from the rainfall.

[1] Acknowledgments are due Mr. J. L. Jacobson for his aid in collecting material in 1914 and to Mr. W. B. Coffman for his general assistance in all phases of this work.

[2] MILLER, E. C. COMPARATIVE STUDY OF THE ROOT SYSTEMS AND LEAF AREAS OF CORN AND THE SORGHUMS. *In* Jour. Agr. Research, v. 6, no. 9, p. 311–332, 3 fig., pl. 38–44. 1916. Literature cited, p. 331.

———. RELATIVE WATER REQUIREMENT OF CORN AND THE SORGHUMS. *In* Jour. Agr. Research, v. 6, no. 13, p. 473–484, 1 fig., pl. 70–72. 1916.

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In order to define better the conditions under which the plants were grown, soil samples for moisture determination were taken for each foot to a depth of 6 feet. This was done either a few days before or after the experimental work with the leaves. The results of these moisture determinations, together with the wilting coefficient and moisture equivalent for the several plots, are shown in Table I.

TABLE I.—*Moisture content of the soil at the time the leaf samples were taken in 1914, 1915, and 1916, at Garden City, Kans.*

Item.	Percentage of moisture, wilting coefficient, and moisture equivalent to a depth of—					
	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.
Corn-milo-kafir plot:						
July 2, 1914	14.6	20.2	21.2	22.8	22.1	21.8
July 10, 1914	11.8	17.1	19.5	23.6	24.6	21.4
July 21, 1914	10.6	13.3	14.5	19.4	22.8	21.7
July 29, 1914	8.7	13.1	13.5	16.8	21.4	21.0
Wilting coefficient	*12.7*	*14.5*	*14.5*	*16.3*	*17.1*	*16.1*
Moisture equivalent	*23.4*	*26.7*	*26.7*	*30.0*	*31.5*	*29.6*
July 29, 1914	10.3	15.7	16.2	18.4	19.8	20.1
August 12, 1914	10.2	14.9	14.1	15.2	17.7	19.6
August 22, 1914	9.5	14.9	14.1	14.4	15.5	18.8
July 12, 1915	16.2	20.8	20.2	17.8	19.0	15.5
August 6, 1915	14.2	15.2	15.4	16.0	16.1	15.4
Wilting coefficient	*13.3*	*14.1*	*14.9*	*13.6*	*13.4*	*11.9*
Moisture equivalent	*24.4*	*25.9*	*27.5*	*25.1*	*24.6*	*21.9*
Corn plot:						
July 20, 1916	10.0	14.7	19.0	21.9	23.6	24.2
August 1, 1916	7.3	11.8	14.0	18.1	21.4	22.0
August 10, 1916	7.5	11.5	12.5	14.6	18.7	20.8
Wilting coefficient	*12.3*	*15.9*	*12.4*	*15.0*	*16.3*	*16.4*
Moisture equivalent	*22.6*	*29.3*	*23.0*	*27.7*	*30.1*	*30.2*
Milo plot:						
July 20, 1916	11.1	15.4	19.6	22.2	24.1	24.8
August 1, 1916	8.3	9.9	14.6	14.9	20.8	24.0
August 10, 1916	8.0	11.8	14.1	13.6	18.6	21.4
Wilting coefficient	*12.2*	*13.4*	*15.1*	*14.3*	*15.4*	*15.6*
Moisture equivalent	*22.4*	*24.6*	*27.8*	*26.3*	*28.3*	*28.6*
Kafir plot:						
August 10, 1916	7.0	11.0	11.7	13.6	21.1	22.6
Wilting coefficient	*12.7*	*12.3*	*15.3*	*13.9*	*16.9*	*17.8*
Moisture equivalent	*23.3*	*22.5*	*28.2*	*25.6*	*31.3*	*32.8*
July 26, 1916	10.8	16.9	19.3	21.9	22.1	21.2
Wilting coefficient	*12.7*	*14.5*	*14.5*	*16.3*	*17.1*	*16.1*
Moisture equivalent	*23.4*	*26.7*	*26.7*	*30.0*	*31.5*	*29.6*

EVAPORATION

Hourly evaporation was determined by Livingston's porous-cup atmometers with a coefficient of 74. The atmometers were placed 2 feet from the ground and connected with burettes so that readings could be made to 0.1 c. c. These atmometers were renewed every three weeks during the periods of the experiments. The evaporation obtained in this manner for each 2-hour period is shown in Table II.

TABLE II.—*Evaporation (in cubic centimeters) for the different periods of leaf sampling in 1914, 1915, and 1916, at Garden City, Kans.*

Date.	Evaporation for period ending—																				
	A. M.			P. M.						A. M.						P. M.				
	7	9	11	1	3	5	7	9	11	1	3	5	7	9	11	1	3	5	7	9
1914.																				
June 24	....	9.8	14.1	17.4	21.7	18.3	14.5	....	....	....	....	....	....	....	....	....	....	....	....	....
July 9	....	5.8	7.8	11.7	12.1	10.8	11.3	3.8	....	....	....	....	....	....	....	....	....	....	....	....
July 13	....	3.7	5.3	8.6	9.7	9.0	9.7	4.3	2.0	....	....	....	....	....	....	....	....	....	....	....
July 22	....	2.8	6.1	8.1	9.5	7.0	4.1	2.9	....	3.5	2.3	1.5	....	....	....	....	....	....	....	....
July 28–29	....	6.4	9.9	14.6	15.8	15.2	13.7	5.6	4.6	....	....	....	....	....	....	....	....	....	....	....
Aug. 3–4	....	5.3	9.7	10.5	11.2	11.3	8.7	4.0	2.9	3.6	2.4	2.3	2.8	6.5	13.7	15.6	....	....	....	....
Aug. 10–11	4.0	7.8	12.1	13.2	14.6	12.7	8.7	5.3	4.3	1.9	0.7	0.6	2.0	5.8	8.8	12.5	4.3	2.2	....	....
Aug. 15–16	2.0	9.4	13.1	18.3	23.8	21.6	14.0	8.4	6.8	4.9	2.7	1.2	3.2	9.8	16.7	23.6	24.7	20.8	16.5	8.1
Aug. 25–26	....	6.3	11.5	13.8	13.3	12.2	9.8	5.6	3.8	2.7	0.6	1.8	3.1	6.3	9.7	12.1	14.9	13.9	8.8	4.9
1915.																				
July 17–18	4.4	8.0	11.6	15.2	16.5	15.7	11.2	4.3	3.9	4.1	3.4	1.8	3.1	....	....	....	....	....	....	....
July 31–Aug. 1	0.8	5.1	9.0	12.7	13.0	10.6	6.6	3.0	1.5	1.1	0.5	0.9	1.7	4.5	8.3	11.7	12.5	13.1	9.1	....
1916.																				
July 20–21	2.0	4.9	7.5	11.8	14.3	14.6	13.5	8.1	7.1	2.5	1.5	1.0	3.6	9.3	12.8	15.3	17.8	....	....	....
July 26–27	7.2	10.2	15.3	18.2	18.7	19.0	16.5	10.2	7.6	4.2	2.3	1.5	3.4	8.3	10.7	15.3	16.9	16.4	12.9	....
Aug. 1–2	3.4	8.5	14.5	17.0	18.1	15.5	12.8	8.7	7.4	5.5	4.5	3.6	5.2	11.6	18.3	20.3	20.6	19.5	....	....
Aug. 10–11	3.2	7.6	13.6	13.3	14.1	15.8	12.9	10.6	4.7	5.6	5.4	3.1	3.7	6.6	8.9	12.9	15.3	14.7	9.2	....

LEAF SAMPLING

The amount of water and dry matter in the leaves of a given variety of plant was determined every two hours from 30 leaf samples, each with an area of 1 square centimeter. Thirty representative plants of each variety were selected and a leaf chosen on each plant for furnishing all the samples for an experiment extending over the desired length of time. Plate 3 shows the manner in which the leaf samples were obtained. This figure shows the appearance of milo, corn, and kafir leaves at the end of a 40-hour experiment. At 7 a. m. a single sample was taken from each of the 30 selected leaves at *a* and toward the tip of the leaf. This was done by means of a Ganong leaf punch taking an area of 1 square centimeter. At 9 a. m. a sample was taken from each of the 30 leaves at *b*, directly opposite *a*. At 11 a. m. the samples were collected from the leaves at *c*, directly below *a*, then at the next 2-hour period at *d*, and so on. The samples for a 40-hour experiment were thus obtained from a portion of the leaves representing less than 6 inches of their respective lengths. The leaf samples from corn, kafir, and milo at any period could be collected in the manner described in from five to eight minutes. Care was taken in the selection of the leaves, so that they would be as nearly the same age as possible for the three plants. The uppermost fully developed leaf of each plant was the one from which the leaf samples were obtained.

The samples were collected in weighed vials which were then quickly stoppered. The vials containing the moist material were weighed at once on balances sensitive to 0.1 mgm. They were then placed in a

drying oven at 100° to 105° C. until all the moisture was driven off. After drying, the samples were cooled in a desiccator over sulphuric acid and weighed, so that the amount of water and dry matter could be obtained.

STAGES EXAMINED

The experiments for the three years were conducted with plants at approximately five stages of development.

STAGE I.—The corn plants had a height of 1 foot 6 inches and possessed 4 fully and 4 partially unfolded leaves. The milo and kafir had the same number of leaves as the corn, but the plants had reached a height of only 1 foot. The experiments of June 24 and July 9, 1914, were conducted with plants at this stage of development.

STAGE II.—The experiments reported for July 13 and 22, 1914, and for July 20–21 and 26–27, 1916, were made with plants at this stage. The corn plants were from 3 feet to 3 feet 6 inches high and had 8 to 10 fully unfolded and 3 to 5 partially unfolded leaves. The Dwarf milo stood 2 feet high and was just beginning to "boot," while the Blackhull kafir had 6 fully and 4 partially unfolded leaves and had reached a height of from 2 feet to 2 feet 6 inches.

STAGE III.—The corn had reached a height of from 4 to 5 feet. The plants had from 12 to 14 leaves and the tassels were just showing. The kafir stood 3 feet 6 inches high and showed 8 fully and 3 partially unfolded leaves. The milo plants were just past the "booting" stage and had from 10 to 12 leaves on a plant. The experiments of July 17 and 18, 1915, and of August 1 and 2, 1916, were conducted with plants at this period of growth.

STAGE IV.—Plants at this stage of development furnished the material for experiments carried on July 28–29, August 3–4, 10–11, 15–16, 1914; July 31, August 1, 1915, and for the experiment of August 10–11, 1916. The corn plants had reached their full leaf development, and the ears were beginning to form. The kafir stood 4 to 5 feet high, and in most cases the plants were just beginning to "boot." The milo was 3 feet 6 inches high and for the various experiments was in stages of development from blooming to the milk stage of the grain.

STAGE V.—The experiment of August 25–26, 1916, was the only one conducted at this period of development. The grain of the corn had reached the early milk stage, the kafir was in bloom, and the grain of the milo was ready to harvest.

GENERAL DISCUSSION OF EXPERIMENTAL DATA

Nine experiments were conducted in 1914, two in 1915, and four in 1916. Four of the experiments in 1914 extended only through the daylight hours, but all of the other experiments ranged in length from 24 to 40 hours. In all, the amount of water and dry matter in the leaves was

determined every two hours for 22 days and 10 nights. The amount of water in the leaves at any period of the night could be accurately determined, owing to the fact that dew is very rare during the summer in this portion of the Great Plains. Corn, kafir, and milo were used in all the experiments, with but two exceptions in 1916. In these two experiments only corn and milo were used. The results for the three years are shown in Tables III and IV. The amount of water in the leaves is expressed in grams per square meter of leaf; percentage on a wet basis and dry basis for each 2-hour period of the experiment. The amount of dry matter is expressed in grams per square meter of leaf and in percentage of the moist weight of the leaf. The data shown in Tables III (July 28, 1914–Aug. 11, 1916) and IV are expressed graphically in figures 1 to 10. In discussing these data the day periods include the determinations made from 7 a. m. to 7 p. m., inclusive, and the night periods include the observations made from 7 p. m. to 7 a. m., inclusive.

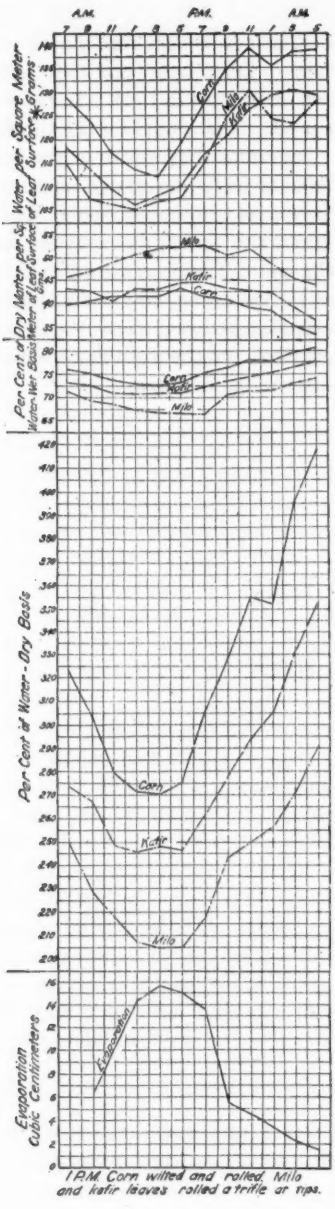


FIG. 1.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for July 28 and 29, 1914, and the evaporation for the corresponding period.

* Leaf surface is used in these figures as the equivalent of leaf area.

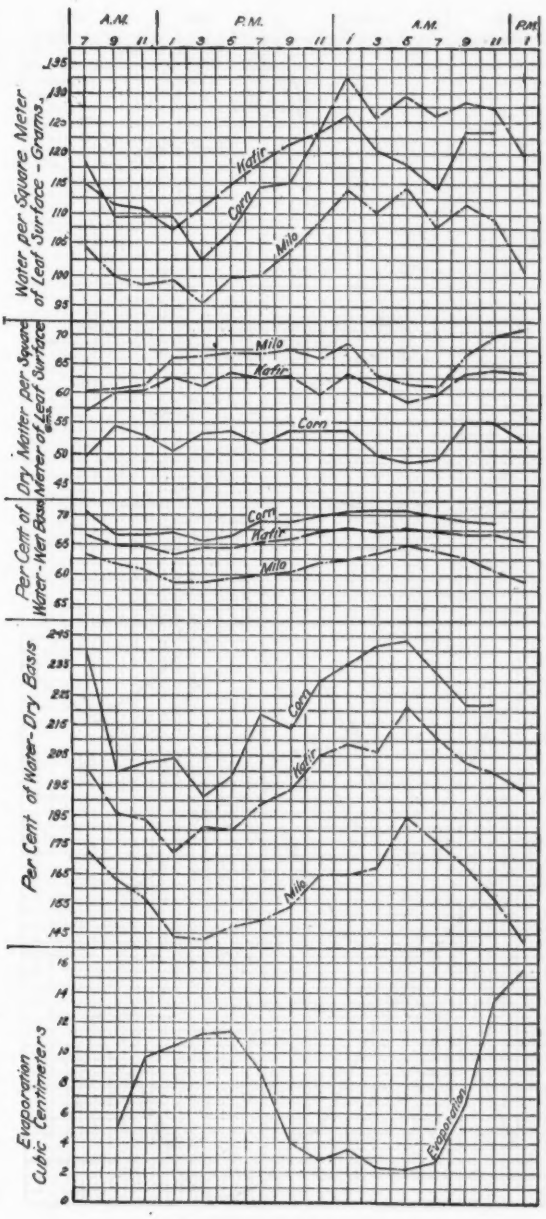


FIG. 2.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for August 3 and 4, 1914, and the evaporation for the corresponding period.

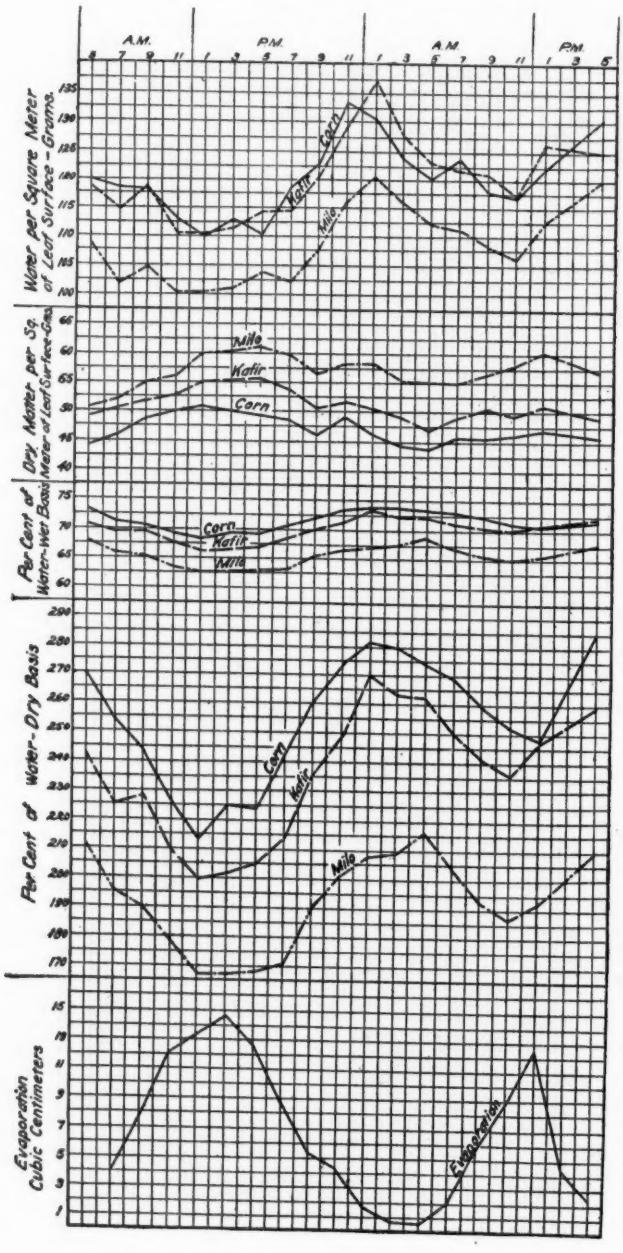
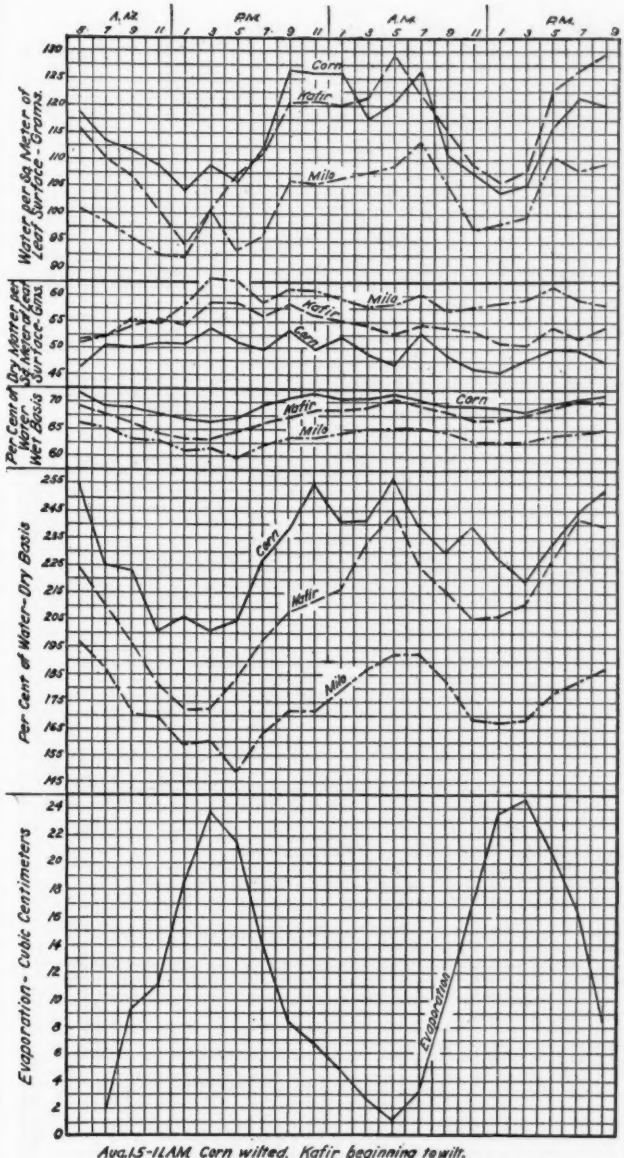


FIG. 3.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for August 10 and 11, 1914, and the evaporation for the corresponding period.



Aug. 15 - 11 A.M. Corn wilted. Kafir beginning to wilt.
5 P.M. Leaves about normal, Milo did not wilt at all.
Aug. 16 - 3 A.M. Guttation showing on kafir.
1 P.M. Corn and kafir wilted. Hot winds. Upper leaves of milo rolled a trifle.

FIG. 4.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for August 15 and 16, 1914, and the evaporation for the corresponding period.

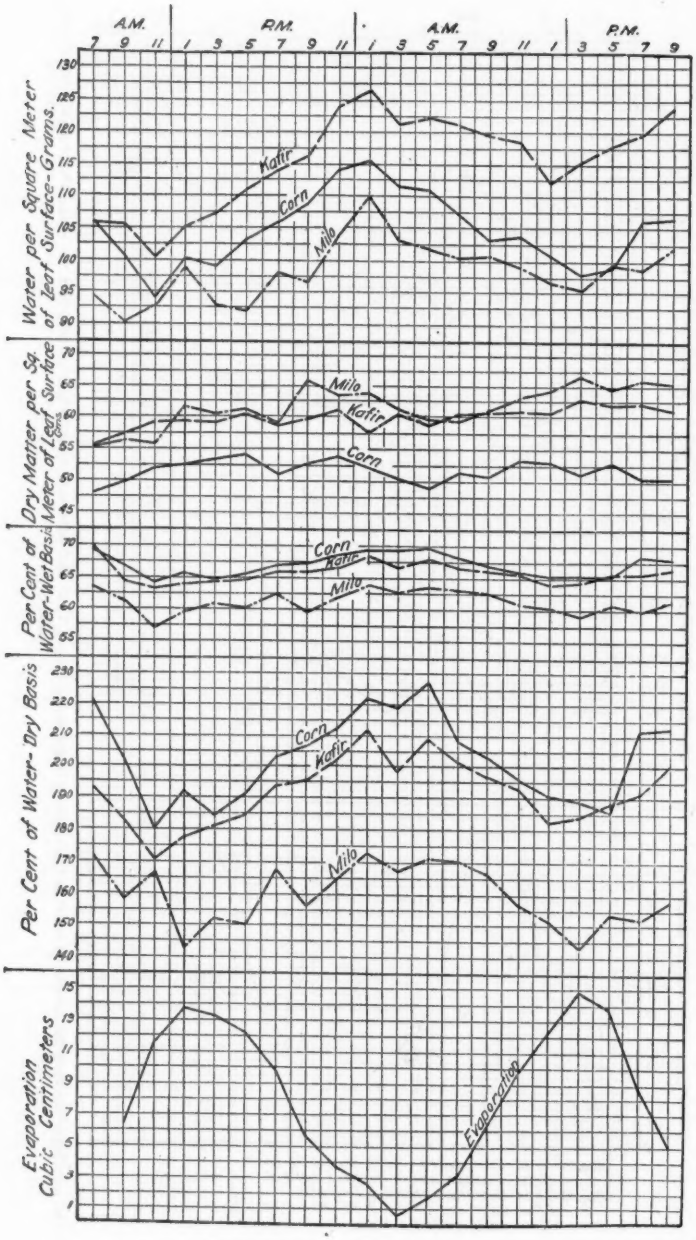


FIG. 5.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for August 25 and 26, 1914, and the evaporation for the corresponding period.

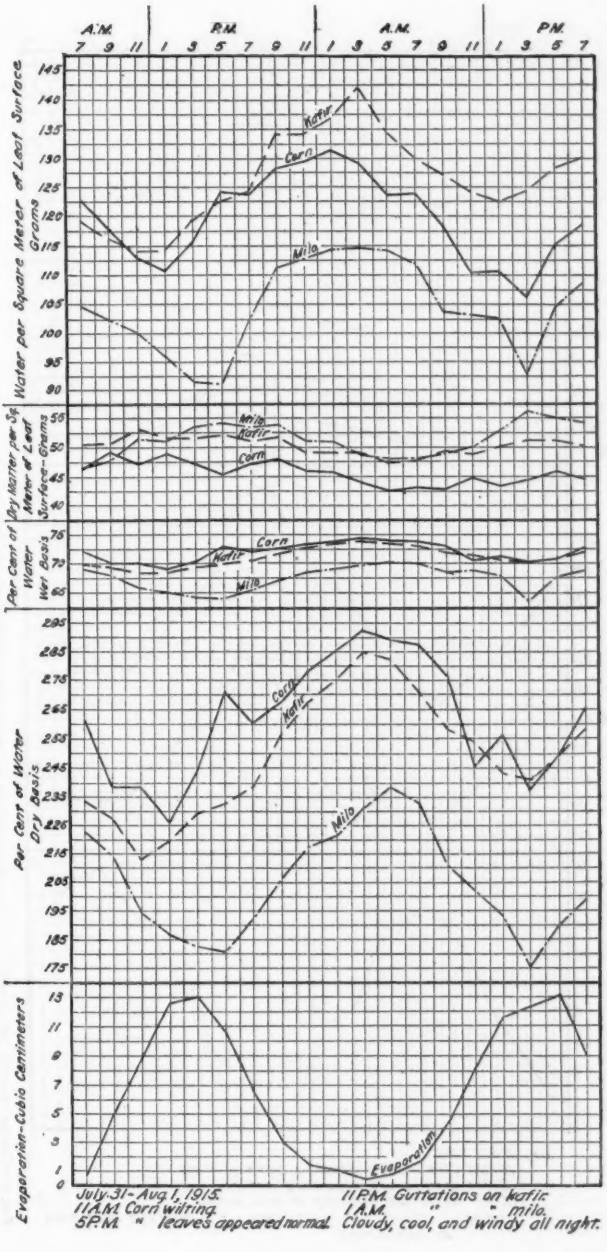


FIG. 6.—Graphs showing the amount of water and dry matter in the leaves of corn, kafir, and milo for July 13 and August 1, 1915, and the evaporation for the same period.

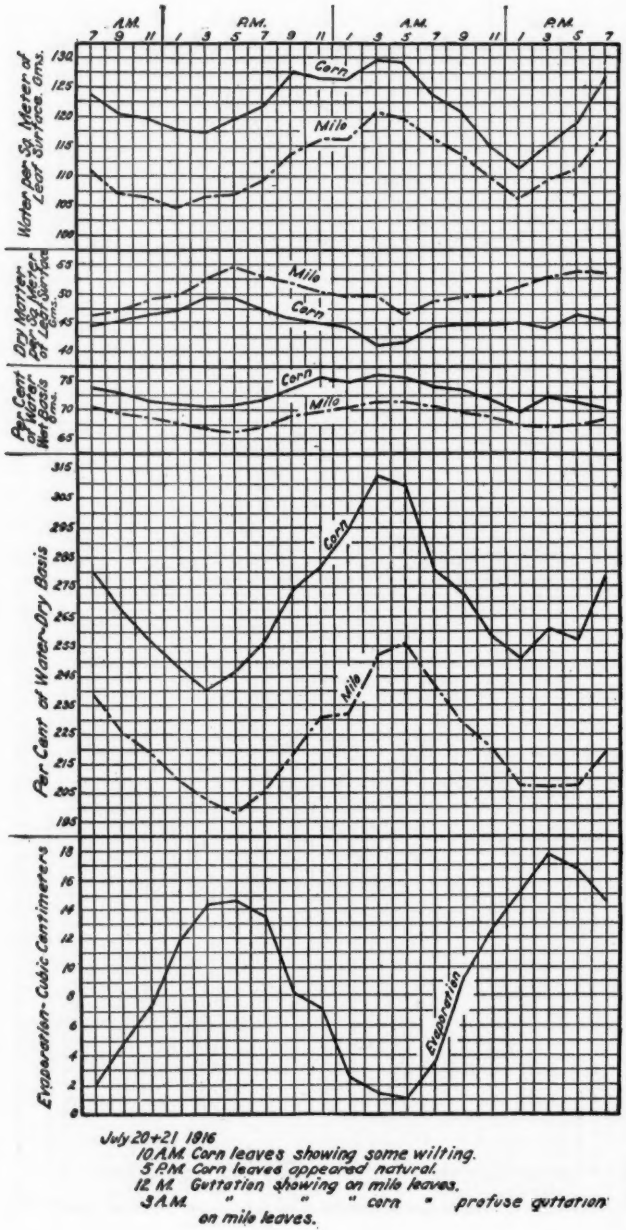

A.M.
P.M.
A.M.
P.M.
7 9 11 1 3 5 7 9 11 1 3 5 7 9 11 1 3 5 7
Water per Sq. Meter of Leaf Surface. Grms.
130 125 120 115 110 105 100
Corn
Milo
Dry Matter per Sq. Meter of Leaf Surface Grms.
Milo
Corn
Per Cent of Water Wet Basis
Corn
Milo
Per Cent of Water-Dry Basis
315 305 295 285 275 265 255 245 235 225 215 205 195
Corn
Milo
Evaporation- Cubic Centimeters
18 16 14 12 10 8 6 4 2 0
Evaporation
July 20+21 1916
10 A.M. Corn leaves showing some wilting.
5 P.M. Corn leaves appeared natural.
12 M. Guttation showing on milo leaves.
3 A.M. " " " corn " profuse guttation on milo leaves.

FIG. 7.—Graphs showing the amount of water and dry matter in the leaves of corn and milo for July 20 and 21, 1916, and the evaporation for the corresponding period.

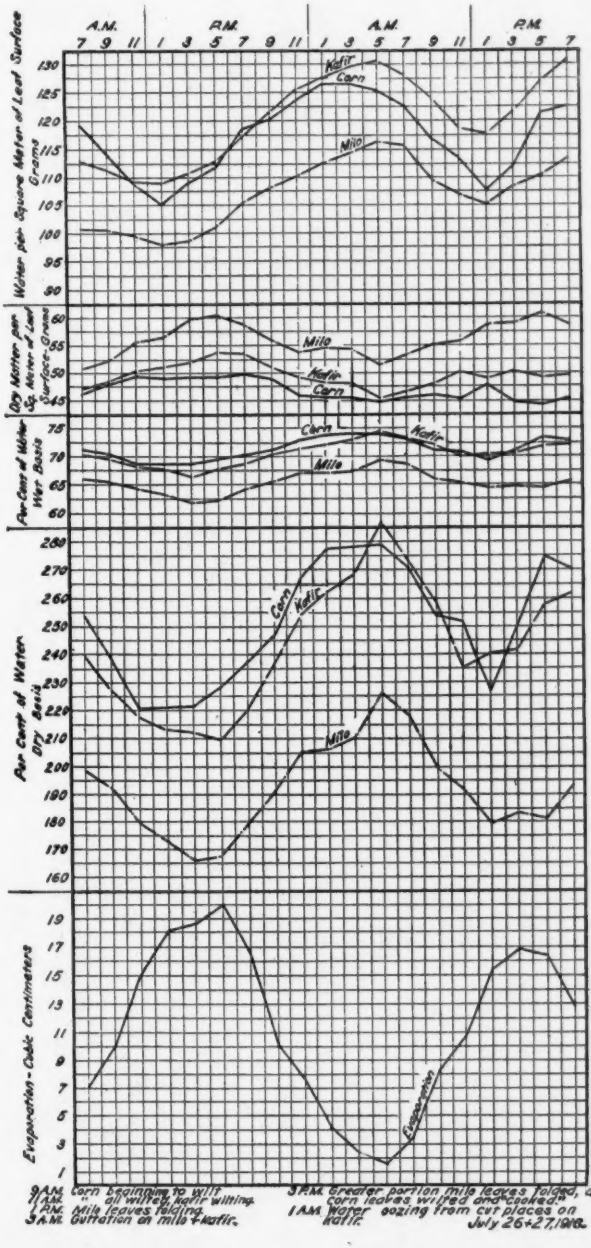

A.M.
P.M.
A.M.
P.M.
7 9 11 1 3 5 7 9 11 1 3 5 7 9 11 1 3 5 7
Water per Square Meter of Leaf Surface Grams
Kafir
Corn
Milo
Dry Matter per Sq. Meter of Leaf Surface Grams
Milo
Kafir
Corn
Per Cent of Water Wet Basis
Corn
Kafir
Milo
Per Cent of Water Dry Basis
Corn
Kafir
Milo
Evaporation - Cubic Centimeters
Evaporation
9 A.M. Corn beginning to wilt
11 A.M. " all wilted, kafir wilting.
1 P.M. Milo leaves folding.
3 A.M. Guttation on milo + kafir.
3 P.M. Greater portion milo leaves folded, all corn leaves wilted and "coiled".
1 A.M. Water oozing from cut places on kafir.
July 26+27, 1916.

FIG. 8.—Graphs showing the amount of water in the leaves of corn, kafir, and milo for July 26 and 27, 1916, and the evaporation for the corresponding period.

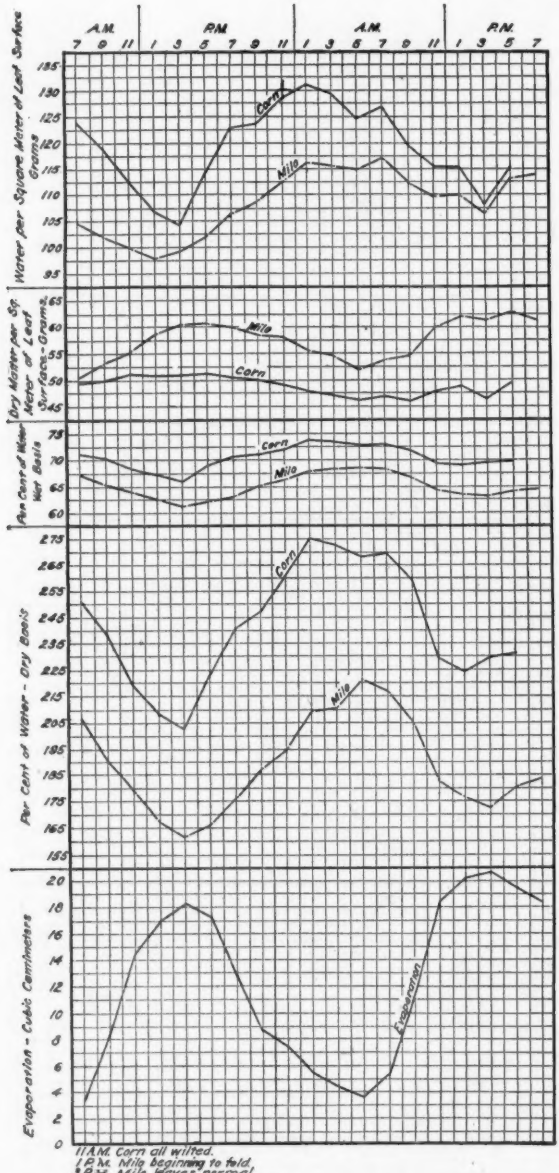

A.M.
P.M.
A.M.
P.M.
7 9 11 1 3 5 7 9 11 1 3 5 7 9 11 1 3 5 7
Water per Square Meter of Leaf Surface Grams
Corn
Milo
Dry Matter per Sq Meter of Leaf Surface-Grams
Milo
Corn
Per Cent of Water Wet Basis
Corn
Milo
Per Cent of Water - Dry Basis
Corn
Milo
Evaporation - Cubic Centimeters
Evaporation
11 A.M. Corn all wilted.
1 P.M. Milo beginning to fold.
3 P.M. Milo leaves normal.
4 P.M. Corn leaves getting turgid.
7 P.M. " " apparently to normal turgidity.
1-6 A.M. Water oozed from cut portions of milo. No guttation at any time of the night.

FIG. 9.—Graphs showing the amount of water in the leaves of corn and milo for August 1 and 2, 1916, and the evaporation for the corresponding period.

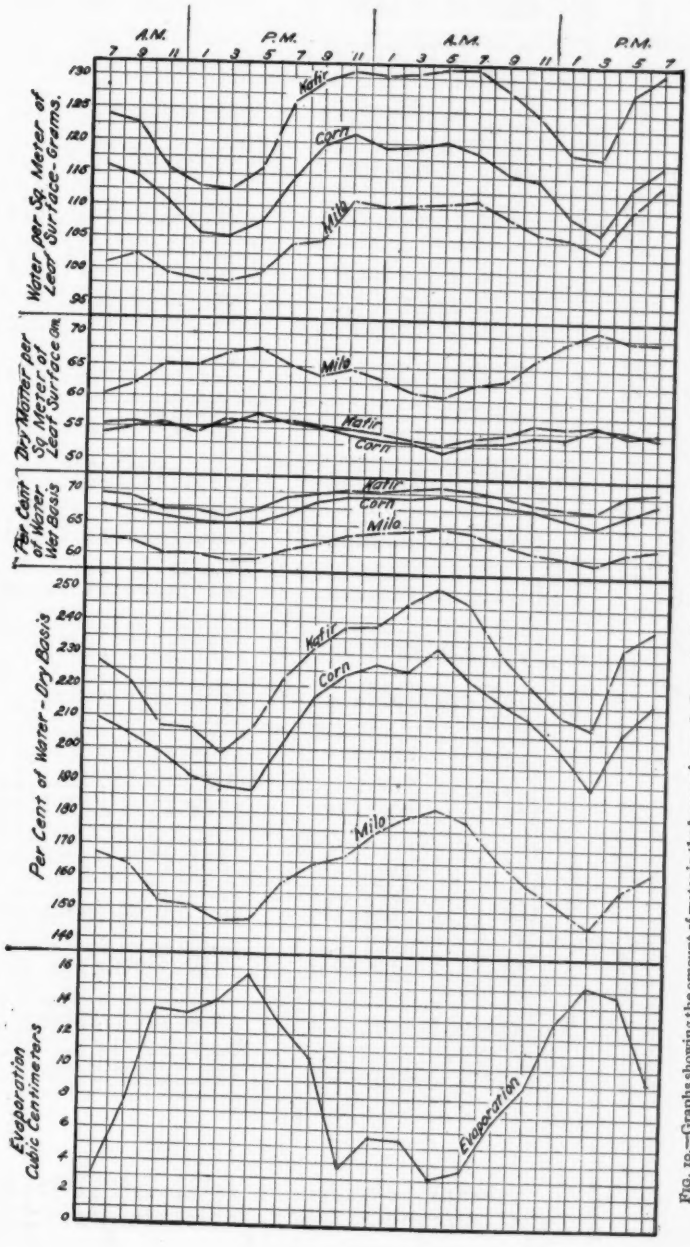


FIG. 10.—Graphs showing the amount of water in the leaves of corn, kafir, and milo for August 10 and 11, 1916, with the evaporation for the corresponding period.

TABLE III.—*Variation of the water and dry matter in the leaves of Pride of Saline corn, Blackhull kafir, and Dwarf milo at Garden City, Kans.*

JUNE 24 AND JULY 9, 1914

Period ending—	Water in 30 samples.			Dry matter in 30 samples.			Water per square meter of leaf.			Dry matter per square meter of leaf.			Percentage of water, wet basis.			Percentage of dry matter.			Percentage of water, dry basis.		
	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.
June 24:	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*									
7 a. m.	476.6	403.6	378.0	95.4	85.4	96.0	158.8	134.5	126.0	31.8	28.5	32.0	83.3	82.5	79.5	16.7	17.5	20.5	499.2	472.2	393.6
9 a. m.	434.6	385.4	362.6	102.8	88.0	103.7	144.9	128.5	120.9	34.3	29.9	34.6	80.8	81.4	77.7	19.2	18.6	22.3	422.7	437.7	349.6
11 a. m.	427.4	374.8	359.8	110.4	100.6	106.2	142.5	124.9	119.9	36.8	33.5	35.4	79.4	78.8	77.2	20.6	21.2	22.8	387.1	372.5	338.7
1 p. m.	444.8	386.4	363.4	107.0	98.6	100.0	148.3	128.8	121.3	35.7	32.9	33.3	80.6	79.6	78.4	19.4	20.4	21.6	415.7	391.8	363.4
3 p. m.	443.0	384.4	355.2	109.8	113.4	121.6	147.7	128.1	118.4	36.6	37.8	40.5	80.1	77.2	74.4	19.9	22.8	25.6	403.4	338.9	292.1
5 p. m.	450.0	386.6	333.0	113.4	114.6	126.4	150.0	128.9	111.0	37.8	38.3	42.1	79.8	77.1	72.4	20.2	22.9	27.6	396.8	337.6	233.4
7 p. m.	461.7	397.0	366.2	105.4	108.4	111.6	153.9	132.3	122.0	35.1	36.1	37.2	81.4	78.5	76.6	18.6	21.5	23.4	438.0	366.2	328.1
July 9:																					
7 a. m.	389.2	388.2	339.5	127.2	136.4	149.6	129.7	129.4	113.2	42.4	45.7	49.9	75.3	73.9	69.4	24.7	26.1	30.6	305.9	284.6	226.9
9 a. m.	366.0	371.6	332.2	142.2	142.8	154.4	122.0	123.8	110.7	47.4	47.6	51.5	72.0	72.2	68.2	28.0	27.8	31.8	257.3	260.2	215.1
11 a. m.	379.2	375.2	325.4	130.2	143.0	161.2	126.4	125.1	108.5	43.4	47.7	53.7	74.4	72.4	66.8	25.6	27.6	33.2	291.2	262.3	201.8
1 p. m.	370.4	374.6	326.0	145.0	141.8	165.3	123.5	124.9	108.7	48.3	47.3	55.1	71.8	72.5	66.3	28.2	27.5	33.7	255.4	264.1	197.2
3 p. m.	374.2	368.4	319.2	150.6	150.4	169.2	124.7	122.8	106.4	50.2	50.1	56.4	71.3	71.0	65.3	28.7	29.0	34.7	248.4	244.9	188.6
5 p. m.	364.2	376.5	331.4	152.8	151.5	164.4	121.4	125.5	110.5	50.9	50.5	54.8	70.4	71.3	66.8	29.6	28.7	33.2	238.3	248.5	201.5
7 p. m.	389.4	386.4	335.8	140.8	143.4	161.6	129.8	128.8	111.9	46.9	47.8	53.9	73.4	72.9	67.4	26.6	27.1	32.6	276.5	269.4	207.7
9 p. m.	406.2	399.0	355.0	136.8	144.0	163.0	135.4	133.0	118.3	45.6	48.7	54.3	74.8	73.4	68.5	25.2	26.6	31.5	296.9	277.0	217.7

JULY 13 AND 22, 1914

July 13:																					
7 a. m.	397.4	372.9	346.0	130.9	132.9	138.4	132.5	120.2	115.3	43.6	44.3	46.1	75.2	73.7	71.4	24.8	26.3	28.6	303.5	280.5	250.0
9 a. m.	388.4	360.6	340.6	132.6	135.9	141.2	129.5	120.2	113.5	44.2	45.3	47.1	74.5	72.6	70.6	25.5	27.4	29.4	292.9	265.3	241.2
11 a. m.	371.0	357.2	329.8	137.4	140.4	147.8	123.7	119.1	109.9	45.8	46.8	49.3	72.9	71.7	69.0	27.1	28.3	31.0	270.0	254.4	223.1
1 p. m.	372.6	352.6	321.0	143.4	144.7	155.6	124.2	117.5	107.0	47.8	48.2	51.9	72.2	70.9	67.3	27.8	29.1	32.7	259.8	243.6	206.2
3 p. m.	378.6	355.8	327.6	142.0	146.6	156.2	126.2	118.6	109.2	47.3	48.9	52.1	72.7	70.8	67.7	27.3	29.2	32.3	266.6	242.7	209.7
5 p. m.	377.8	365.2	335.0	146.4	150.8	161.0	125.9	121.7	111.7	48.8	50.3	53.7	72.0	70.7	67.5	28.0	29.3	32.5	258.0	242.1	208.0
7 p. m.	394.4	375.8	353.0	141.7	143.4	158.0	131.5	125.3	117.7	47.2	47.8	52.7	73.5	72.3	69.0	26.5	27.7	31.0	278.3	262.0	223.4
9 p. m.	406.6	390.8	366.6	136.6	140.4	152.6	135.5	130.3	122.2	45.5	46.8	50.7	74.8	73.5	70.6	25.2	26.5	29.4	297.6	278.3	240.2
11 p. m.	405.0	405.4	391.4	130.2	138.2	147.8	135.0	135.1	130.5	43.4	46.1	49.3	75.6	74.5	72.5	24.4	25.5	27.5	317.0	293.3	264.8
July 22:																					
7 a. m.	376.8	356.6	336.4	136.2	147.4	165.8	125.6	118.9	112.1	45.4	49.1	55.3	73.4	70.7	67.0	26.6	29.3	33.0	276.6	241.9	202.8
9 a. m.	369.2	350.2	324.4	130.8	152.4	161.0	123.1	116.7	108.1	46.9	50.8	53.7	72.3	69.6	66.8	27.7	30.4	33.2	262.2	229.7	201.4
11 a. m.	356.8	340.8	314.8	147.6	155.6	154.4	118.9	113.6	104.9	49.2	51.9	51.5	70.7	68.6	67.0	29.3	31.4	33.0	241.7	219.0	203.8
1 p. m.	359.4	328.8	315.2	152.6	158.6	172.8	119.8	109.6	105.1	50.9	52.9	57.6	70.1	67.4	64.5	29.9	32.6	35.5	235.5	207.3	182.4
3 p. m.	.....	334.8	312.8	150.4	161.4	179.8	.....	111.6	104.3	50.1	53.8	59.9	.....	67.4	63.4	.....	32.6	36.6	.....	207.4	173.9
5 p. m.	376.8	339.4	324.2	153.4	159.2	173.2	125.6	113.1	108.1	51.1	53.1	57.7	71.0	68.0	65.1	29.0	32.0	34.9	245.6	213.1	187.1
7 p. m.	367.8	356.4	350.4	143.0	157.8	173.4	122.6	118.9	116.8	47.7	52.6	57.8	72.0	69.3	66.8	28.0	30.7	33.2	257.2	226.1	202.0
9 a. m.	413.6	380.8	373.8	145.6	158.8	178.6	137.9	126.9	124.6	48.5	52.9	59.5	73.9	70.5	67.7	26.1	29.5	32.3	284.0	239.7	209.2

JULY 28 AND 29, 1914

July 28:																					
7 a. m.	387.0	354.6	344.8	119.6	129.4	138.2	129.0	118.2	114.9	39.9	43.1	46.1	76.3	73.2	71.3	23.7	26.8	28.7	323.5	274.0	249.4
9 a. m.	372.2	341.4	323.0	122.4	127.8	141.0	124.1	113.8	107.7	40.8	42.6	47.0	75.2	72.7	69.6	24.8	27.3	30.4	304.0	267.1	229.0
11 a. m.	351.8	329.8	320.0	125.8	132.4	147.0	117.3	109.9	106.7	41.9	40.8	49.0	73.6	71.3	68.5	26.4	28.7	31.5	279.6	249.0	217.6
1 p. m.	340.8	320.4	316.2	125.6	130.2	152.2	113.6	106.8	105.4	41.9	43.4	50.7	73.0	71.1	67.5	27.0	28.9	32.5	271.3	246.0	207.7
3 p. m.	337.2	324.2	322.2	124.8	130.4	157.0	112.4	108.1	107.4	41.6	43.1	52.3	72.9	71.3	67.2	27.1	28.7	32.8	270.1	248.5	205.2
5 p. m.	356.6	330.2	323.2	129.4	133.8	157.4	118.9	110.1	107.7	43.1	44.6	52.5	73.3	71.1	67.2	26.7	28.9	32.8	275.5	246.7	205.3
7 p. m.	381.2	350.6	344.4	124.6	134.0	158.2	127.1	116.9	114.8	41.5	44.7	52.7	75.3	72.3	66.5	24.7	27.7	33.5	305.9	261.6	217.6
9 p. m.	404.6	361.2	372.8	123.2	130.0	152.8	134.9	120.4	124.3	41.1	43.3	50.9	76.6	73.5	70.9	23.4	26.5	29.1	328.4	277.8	243.9
11 p. m.	417.6	378.6	390.6	117.6	128.6	156.2	139.2	126.2	130.2	39.2	42.9	52.1	78.0	74.6	71.9	22.0	25.4	28.1	355.1	294.4	250.0
July 29:																					
1 p. m.	407.8	389.6	373.8	115.6	127.2	145.4	135.9	129.2	124.6	38.5	42.4	48.5	77.9	75.4	71.9	22.1	24.6	28.1	352.7	306.2	257.0
3 a. m.	415.8	390.8	370.4	105.2	117.6	136.4	138.6	130.3	123.5	35.1	39.2	45.4	79.8	76.8	73.0	20.2	23.2	27.0	395.2	332.3	271.5
5 a. m.	416.2	388.8	385.8	99.6	110.0	132.6	138.7	129.6	128.6	33.2	36.7	44.2	80.6	77.9	74.4	19.4	22.1	25.6	417.8	353.4	290.9

AUGUST 3 AND 4, 1914

August 3:																					
7 a. m.	356.2	345.4	314.2	149.0	171.6	182.2	118.7	115.1	104.7	49.7	57.2	60.7	70.5	66.8	63.2	29.5	33.2	36.8	239.0	201.2	172.4
9 a. m.	329.0	335.8	298.4	164.8	181.0	183.2	109.7	111.9	99.5	54.9	60.3	61.1	66.6	64.7	61.9	33.4	35.3	38.1	199.6	185.5	162.8
11 a. m.	329.2	334.2	295.4	162.4	181.4	188.8	109.7	111.4	98.5	53.1	60.5	61.9	66.9	64.8	61.0	33.1	35.2	39.0	202.7	184.2	156.4
1 p. m.	329.6	322.4	287.0	161.2	187.8	199.6	109.9	107.5	99.0	50.4	62.6	66.5	67.1	63.1	58.9	32.9	36.9	41.1	204.4	171.6	143.7
3 p. m.	307.4	333.4	286.4	160.4	184.4	199.4	102.5	111.1	95.5	53.5	61.5	66.5	65.7	64.3	58.9	34.3	35.7	41.1	191.6	180.8	143.6
5 p. m.	321.0	343.6	299.2	161.4	190.8	203.0	107.0	114.5	99.7	53.8	63.6	67.0	66.5	64.2	59.5	33.5	35.8	40.5	198.8	180.0	147.3
7 p. m.	342.0	354.2	300.2	256.0	187.4	200.8	114.0	118.1	100.1	52.0	62.5	66.9	68.6	65.3	59.9	31.4	34.7	40.1	219.2	189.0	149.5
9 p. m.	346.4	365.0	312.6	161.2	188.8	202.6	115.5	121.7	104.2	53.7	62.9	67.5	68.2	65.9	60.6	31.8	34.1	39.4	214.8	194.1	154.2
11 p. m.	370.8	369.2	326.5	160.8	179.8	198.1	123.6	123.1	108.8	53.6	59.9	66.0	69.7	67.3	62.2	30.3	32.7	37.8	230.5	205.3	164.8
August 4:																					
1 a. m.	379.6	398.0	343.0	160.8	190.2	205.6	126.5	132.7	114.3	53.6	63.4	68.5	70.2	67.6	62.5	29.8	32.4	37.5	236.0	209.2	164.8
3 a. m.	362.2	378.0	330.6	149.4	183.2	188.8	120.7	126.0	110.2	49.8	61.1	62.9	70.7	67.3	63.6	29.3	32.7	36.4	242.4	206.3	166.8
5 a. m.	354.4	388.2	342.2	145.4	175.3	185.0	118.1	129.4	114.1	48.5	58.4	61.7	70.9	70.1	63.9	29.1	29.9	35.1	243.7	221.4	184.9
7 a. m.	342.0	379.0	324.0	147.0	179.6	184.4	114.0	126.3	108.0	49.0	59.9	61.5	69.9	67.1	63.7	30.1	32.9	36.3	232.6	211.0	175.7
9 a. m.	369.2	384.4	335.6	166.6	190.0	200.4	123.1	128.3	111.9	55.5	63.3	66.8	68.9	66.9	62.2	31.1	33.1	37.4	221.6	202.5	167.4
11 a. m.	369.8	381.6	326.8	166.4	191.2	209.6	123.2	127.2	108.9	55.5	63.7	69.9	68.8	66.6	60.9	31.2	33.4	39.1	222.2	199.5	155.9
1 p. m.	.....	359.8	302.0	156.8	190.2	212.6	.....	119.9	100.7	52.3	63.4	70.9	.....	65.4	58.7	.....	34.6	41.3	.....	188.8	142.0

TABLE III.—*Variation of the water and dry matter in the leaves of Pride of Saline corn, Blackhull kafir, and Dwarf milo at Garden City, Kans.*—Con.

AUGUST 10 AND 11, 1914

Period ending—	Water in 30 samples.			Dry matter in 30 samples.			Water per square meter of leaf.			Dry matter per square meter of leaf.			Percentage of water, wet basis.			Percentage of dry matter.			Percentage of water, dry basis.		
	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.
August 10:	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*									
5 a. m.	360.0	354.8	324.8	133.8	146.8	154.4	120.0	118.3	108.3	44.6	48.9	51.5	72.9	70.7	67.7	27.1	29.3	32.3	269.0	241.6	210.3
7 a. m.	354.6	344.6	306.4	140.0	152.8	156.8	118.2	114.9	102.2	46.7	50.9	52.2	71.6	69.2	66.1	28.4	30.8	33.9	253.6	225.5	195.6
9 a. m.	354.2	356.0	314.0	145.4	155.6	165.2	118.1	118.7	104.7	48.5	51.9	55.1	70.8	69.5	65.5	29.2	30.5	34.5	243.6	228.7	190.0
11 a. m.	339.0	333.2	300.2	150.0	158.8	169.0	113.0	110.7	100.7	50.0	52.9	56.3	69.3	67.7	63.9	30.7	32.3	36.1	226.0	209.8	177.6
1 p. m.	328.8	331.0	302.0	154.4	166.0	180.0	109.6	110.3	100.7	51.5	55.3	60.0	68.0	66.5	62.6	32.0	33.5	37.4	212.9	199.3	167.7
3 p. m.	338.2	334.2	303.6	150.2	166.2	181.0	112.7	111.4	101.2	50.1	55.4	60.3	69.2	66.7	62.6	30.8	33.3	37.4	225.1	201.0	167.7
5 p. m.	330.8	342.0	310.6	147.2	166.8	184.0	110.3	114.0	103.5	49.1	55.6	61.3	69.2	67.2	62.7	30.8	32.8	37.3	224.7	205.0	168.8
7 p. m.	354.8	343.0	307.2	145.2	160.2	179.8	118.3	114.3	102.4	48.4	53.4	59.9	70.9	68.1	63.0	29.1	31.9	37.0	244.3	214.1	170.8
9 p. m.	369.0	362.4	323.0	140.8	152.8	169.0	123.0	120.8	107.7	46.9	50.9	56.3	72.3	70.3	65.6	27.7	29.7	34.4	262.0	237.1	191.1
11 p. m.	400.6	389.6	350.8	145.8	155.8	173.6	133.5	129.9	116.9	48.6	51.9	57.9	73.3	71.4	66.8	26.7	28.6	33.1	274.7	250.0	202.0
August 11:																					
1 a. m.	392.4	412.2	362.6	139.4	152.4	173.8	130.8	137.4	120.9	46.5	50.8	57.9	73.7	73.0	67.5	26.3	27.0	32.5	281.4	270.4	208.6
3 a. m.	370.0	382.4	346.7	132.4	145.2	165.7	123.5	127.5	115.6	44.1	48.4	55.2	73.6	72.4	67.6	26.4	27.6	32.4	279.4	263.3	209.2
5 a. m.	360.4	368.4	336.2	131.6	140.4	156.2	120.1	122.8	112.1	43.9	46.8	52.1	73.2	72.4	68.2	26.8	27.6	31.8	273.8	262.3	215.2
7 a. m.	370.6	365.4	333.8	138.2	146.6	165.0	123.5	121.9	111.3	46.1	48.9	55.0	72.8	71.3	66.9	27.2	28.7	33.1	268.1	249.5	202.3
9 a. m.	353.8	364.8	324.0	137.0	151.4	169.0	117.9	121.6	108.9	45.7	50.5	56.3	72.0	70.6	65.7	28.0	29.4	34.3	258.2	240.9	191.7
11 a. m.	350.8	351.8	320.2	139.4	149.4	172.6	116.9	117.3	106.7	46.5	49.4	57.7	71.5	70.1	65.0	28.5	29.9	35.0	251.6	235.4	185.9
1 p. m.	366.2	379.8	347.6	147.8	154.0	181.0	122.1	126.6	112.5	49.3	51.3	60.3	71.2	71.1	65.7	28.8	28.9	34.3	247.7	246.6	192.0
3 p. m.	392.6	374.8	360.0	137.4	144.4	171.6	130.9	124.9	120.0	45.8	48.1	57.2	74.0	72.1	67.7	26.0	27.9	32.3	285.7	259.5	209.7

AUGUST 15 AND 16, 1914

August 15:																					
5 a. m.	356.0	349.4	303.4	139.6	155.6	153.8	118.7	116.5	101.3	46.5	51.9	51.3	71.8	69.1	66.3	28.2	30.9	33.7	255.0	224.5	197.2
7 a. m.	339.8	331.6	294.2	151.0	157.2	157.2	113.3	110.5	98.1	50.3	52.4	52.4	69.2	67.8	65.1	30.8	32.2	34.9	225.0	210.9	187.1
9 a. m.	335.0	320.6	285.8	150.2	162.0	166.8	111.7	106.9	95.3	50.1	54.0	55.6	69.0	66.4	63.1	31.0	33.6	36.9	223.0	196.9	171.3
11 a. m.	324.4	301.2	277.6	152.8	165.8	163.8	108.1	100.4	92.5	50.9	55.3	54.6	67.9	64.4	62.8	32.1	35.6	37.2	200.4	181.6	169.4
1 p. m.	313.2	282.6	276.0	152.6	163.8	174.0	104.4	94.2	92.0	50.9	54.6	58.0	67.2	63.3	61.3	32.8	36.7	38.7	205.2	172.5	158.6
3 p. m.	324.4	302.2	303.8	161.8	174.8	189.2	108.1	100.7	101.3	53.9	58.3	63.1	66.7	63.3	61.6	33.3	36.7	38.4	200.4	172.8	160.5
5 p. m.	317.2	322.0	280.0	154.8	175.0	188.4	105.7	107.3	93.3	51.6	58.3	62.8	67.2	64.7	59.7	32.8	35.3	40.3	204.9	184.0	148.6
7 p. m.	337.2	334.6	288.9	149.0	169.2	176.4	112.4	111.5	96.3	49.7	56.4	58.8	69.3	66.4	62.0	30.7	33.6	38.0	226.3	197.7	163.7
9 p. m.	380.8	361.4	318.2	159.6	174.2	184.8	126.7	120.5	106.1	53.2	58.1	61.6	70.4	67.4	63.2	29.6	32.6	36.8	238.5	207.4	172.1
11 p. m.	378.2	362.6	316.0	148.4	169.8	183.8	126.1	120.9	105.3	49.5	56.6	61.3	71.8	68.1	63.2	28.2	31.9	36.8	254.8	213.5	171.9

August 16:																				
1 a. m.	378.4	360.3	318.8	157.0	166.6	177.6	126.1	120.0	106.3	52.3	55.5	59.2	70.6	68.3	64.2	29.4	31.7	35.8	241.0	216.0	179.5
3 a. m.	352.4	365.8	322.6	146.0	163.6	173.0	117.5	121.9	107.5	48.7	54.3	57.7	70.7	69.0	65.0	29.3	31.0	35.0	241.3	233.5	186.4
5 a. m.	362.2	388.2	326.4	141.4	158.6	174.0	120.7	129.4	108.8	47.1	52.9	58.0	71.9	70.7	65.2	28.1	29.3	34.8	256.1	244.7	187.5
7 a. m.	379.8	366.4	339.6	158.6	163.0	181.0	126.6	122.1	113.2	52.9	54.3	60.3	70.5	69.2	65.2	29.5	30.8	34.8	239.4	224.7	187.6
9 a. m.	335.2	347.8	315.2	145.8	161.6	171.6	111.7	115.9	105.1	48.6	53.9	57.2	69.6	68.2	64.7	30.4	31.8	35.3	229.9	215.2	183.6
11 a. m.	322.0	326.6	291.6	139.4	159.2	173.0	107.4	108.9	97.2	46.4	53.1	57.7	69.7	67.2	62.7	30.3	32.8	37.3	239.4	205.1	168.5
1 p. m.	311.2	316.6	293.6	136.8	153.6	175.2	103.7	105.5	97.9	45.6	51.2	58.4	69.4	67.3	62.6	30.6	32.7	37.4	227.4	206.1	167.5
3 p. m.	315.8	323.4	299.5	144.0	153.0	178.0	105.3	107.8	99.8	48.0	51.0	59.3	70.0	69.4	64.0	30.0	30.6	36.0	233.4	227.0	178.3
5 p. m.	350.2	368.8	332.0	150.0	162.4	186.2	116.7	122.9	110.7	50.0	54.1	62.1	71.0	70.8	64.6	29.0	29.2	35.4	244.9	242.5	182.5
7 p. m.	365.4	380.0	324.6	149.2	156.6	177.8	121.8	126.7	108.2	49.7	52.2	59.3	71.6	70.5	65.1	28.4	29.5	34.9	252.8	239.8	187.3
9 p. m.	360.6	389.0	328.6	142.6	162.2	175.4	120.2	129.7	109.5	47.5	54.1	58.5									

AUGUST 25 AND 26, 1914

August 25:																				
7 a. m.	319.6	318.4	283.2	143.4	167.2	165.0	106.5	106.1	94.4	47.8	55.7	55.0	69.0	69.8	63.1	31.0	30.2	36.9	222.8	193.9	171.6
9 a. m.	305.4	316.8	271.0	149.7	172.2	170.2	101.8	105.6	90.3	49.9	57.4	56.7	67.1	64.7	61.4	32.9	35.2	38.6	204.0	183.9	159.2
11 a. m.	282.7	301.8	278.4	156.8	177.4	168.0	94.0	100.6	92.8	52.3	59.1	56.0	64.3	62.9	57.2	35.7	37.1	42.8	180.2	170.1	165.7
1 p. m.	302.0	315.6	265.6	157.6	178.0	185.4	100.7	105.2	98.5	52.5	59.3	61.8	65.7	63.9	58.9	34.3	36.1	41.1	191.6	177.3	143.2
3 p. m.	294.2	321.0	278.4	159.8	178.0	182.8	98.1	107.0	92.8	53.3	59.3	60.9	64.8	64.3	60.3	35.2	35.7	39.7	184.7	180.3	152.2
5 p. m.	310.4	334.4	276.4	163.0	181.2	184.0	103.1	111.5	92.1	54.3	60.4	61.3	65.5	64.8	60.0	34.5	35.2	40.0	190.4	184.5	150.2
7 p. m.	317.4	341.4	293.4	155.8	176.0	176.2	105.8	113.8	97.8	51.9	58.7	58.7	67.0	65.9	62.4	33.0	34.1	37.6	203.7	193.9	166.5
9 p. m.	324.8	349.4	290.6	157.8	179.0	196.2	108.3	116.5	96.9	52.6	59.7	65.4	67.3	66.1	59.6	32.7	33.9	40.4	205.8	195.1	156.0
11 p. m.	340.6	370.4	311.8	161.0	184.0	189.6	113.5	123.5	103.9	53.7	61.3	63.2	67.9	66.8	62.1	32.1	33.2	37.9	211.5	201.3	164.6
August 26:																				
1 a. m.	347.8	380.4	329.2	157.2	179.2	190.0	115.9	126.8	109.7	52.4	57.7	63.3	68.8	67.9	63.4	31.2	32.1	36.6	221.3	212.2	173.2
3 a. m.	335.2	365.0	308.4	152.4	181.4	184.2	111.7	121.7	102.8	50.8	60.5	61.4	68.7	66.8	62.6	31.3	33.2	37.4	219.9	198.3	167.4
5 a. m.	333.0	366.4	306.2	146.6	175.0	179.4	111.0	122.1	102.1	48.9	58.3	59.8	69.4	67.6	63.0	30.6	32.4	37.0	227.1	209.3	170.6
7 a. m.	321.4	364.0	301.4	154.0	181.0	177.2	107.1	121.3	100.5	51.3	60.3	59.1	67.6	66.1	62.9	32.4	33.3	37.1	208.7	201.1	170.2
9 a. m.	308.8	357.2	302.2	152.0	182.0	182.6	102.9	119.1	100.7	50.7	60.7	60.9	67.0	66.2	62.5	33.0	33.8	37.5	203.1	196.2	165.4
11 a. m.	310.4	354.0	295.2	158.8	182.8	188.4	103.5	118.0	98.4	52.9	60.9	62.8	66.1	65.9	61.0	33.9	34.1	39.0	195.4	193.6	156.6
1 p. m.	301.2	335.0	290.6	158.2	182.8	192.4	100.4	111.7	96.9	52.9	60.9	64.1	65.5	64.6	60.1	34.5	35.4	39.9	190.3	183.2	151.0
3 p. m.	292.9	346.6	287.4	154.7	187.8	200.4	97.6	115.5	95.8	51.2	62.6	66.8	65.4	64.8	58.9	34.6	35.2	41.1	189.3	184.5	143.4
5 p. m.	296.6	352.8	296.8	158.0	187.0	194.4	98.9	117.6	98.9	52.7	62.3	64.8	65.2	65.3	60.4	34.8	34.7	39.6	187.7	188.6	152.6
7 p. m.	318.2	358.8	294.6	150.8	187.0	197.2	106.1	119.6	98.2	50.3	62.3	65.7	67.8	65.7	59.9	32.2	34.3	40.1	211.0	191.8	151.9
9 p. m.	319.2	369.2	306.0	151.0	184.4	195.6	106.4	123.1	102.0	50.3	61.5	65.2	67.6	66.6	61.0	32.4	33.4	39.0	211.3	200.2	156.4

TABLE III.—*Variation of the water and dry matter in the leaves of Pride of Saline corn, Blackhull kafir, and Dwarf milo at Garden City, Kans.*—Contd.

JULY 17 AND 18, 1915

Period ending—	Water in 30 samples.			Dry matter in 30 samples.			Water per square meter of leaf.			Dry matter per square meter of leaf.			Percentage of water, wet basis.			Percentage of dry matter.			Percentage of water, dry basis.		
	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.
July 17:	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*									
6 a. m.	414.0	353.0	320.4	128.8	123.8	131.4	180.9	158.9	150.6	42.9	41.3	43.8	76.3	74.0	70.9	23.7	26.0	29.1	321.4	285.1	243.8
8 a. m.	391.8	352.6	312.0	137.2	132.8	133.0	176.3	161.8	148.6	45.7	44.3	44.3	74.1	72.6	70.0	25.9	27.4	30.0	285.6	265.5	234.6
10 a. m.	372.0	343.4	308.6	142.4	134.8	139.8	171.5	159.4	149.5	47.5	44.9	46.6	72.3	71.8	68.8	27.7	28.2	31.2	261.2	254.9	220.7
12 noon	355.8	327.4	294.8	143.0	145.8	148.2	166.3	157.7	147.7	47.7	48.6	49.4	71.3	69.2	66.5	28.7	30.8	33.5	248.8	224.6	198.9
2 p. m.	347.6	329.8	288.0	144.4	155.2	160.0	164.0	161.7	149.3	48.1	51.7	53.3	70.6	68.0	64.3	29.4	32.0	35.3	240.7	212.5	179.8
4 p. m.	351.0	339.6	306.0	143.4	154.8	148.8	164.8	164.8	151.6	47.8	51.6	49.6	71.0	68.7	67.3	29.0	31.7	32.7	244.8	219.4	205.6
6 p. m.	384.4	359.8	304.8	151.8	152.0	166.0	178.7	170.6	156.9	50.6	50.7	55.3	71.7	70.3	64.7	28.3	29.7	35.3	253.2	236.7	183.6
8 p. m.	403.2	372.8	319.6	149.4	149.8	155.4	184.2	174.2	161.7	49.8	49.9	51.8	72.9	71.3	66.0	27.1	28.7	34.0	269.9	248.9	205.7
10 p. m.	400.0	382.8	330.6	134.0	145.0	152.0	178.0	175.9	160.9	44.7	48.3	50.7	74.9	72.5	68.5	25.1	27.5	31.5	298.5	264.0	217.5
July 18:																					
12 midnight	391.7	373.6	333.8	130.6	145.0	150.2	174.1	172.9	161.3	43.5	48.3	50.1	75.0	72.0	69.0	25.0	28.0	31.0	300.0	257.7	222.2
2 a. m.	411.7	390.2	350.0	132.6	141.2	148.2	181.4	177.1	166.1	44.2	47.1	49.4	75.6	73.4	70.3	24.4	26.6	29.7	310.5	276.3	236.2
4 a. m.	417.0	438.6	363.0	133.2	138.0	145.6	183.4	192.2	169.5	44.4	46.0	48.5	75.8	76.1	71.4	24.2	23.9	28.6	313.1	317.8	249.3
6 a. m.	423.0	442.6	368.6	134.4	137.4	145.6	185.8	193.3	171.4	44.8	45.8	48.5	75.9	76.3	71.6	24.1	23.7	28.4	314.7	322.1	252.7

JULY 31 AND AUGUST 1, 1915

July 31:																					
7 a. m.	368.4	357.8	313.6	140.2	153.0	140.4	122.8	119.3	104.5	46.7	51.0	46.8	72.4	70.0	69.1	27.6	30.0	30.9	262.8	233.9	223.2
9 a. m.	354.0	350.2	307.8	148.2	153.7	143.6	118.0	116.7	102.6	49.4	51.2	47.9	70.5	69.5	68.2	29.5	30.5	31.8	238.9	227.8	214.3
11 a. m.	339.3	342.4	301.6	142.1	160.6	155.0	113.1	114.1	100.5	47.4	53.5	51.7	70.5	68.7	66.1	29.5	31.3	33.9	238.8	213.2	194.6
1 p. m.	333.4	343.0	289.4	147.4	156.0	154.8	111.1	114.3	96.5	49.1	52.0	51.6	69.3	68.7	65.2	30.7	31.3	34.8	226.2	219.8	187.0
3 p. m.	348.2	358.0	295.8	142.6	156.0	161.8	116.1	119.3	91.9	47.5	52.0	53.6	70.9	69.6	64.6	29.1	30.4	35.4	244.2	229.6	182.8
5 p. m.	372.0	367.4	295.0	137.0	157.2	163.0	124.0	122.5	91.7	45.7	52.4	54.3	73.1	70.0	64.4	26.9	30.0	35.6	271.5	233.7	181.0
7 p. m.	370.8	371.8	307.8	142.0	155.4	160.2	123.6	123.9	102.6	47.3	51.8	53.4	72.3	70.5	65.8	27.7	29.5	34.2	261.1	239.3	192.1
9 p. m.	384.8	402.2	334.6	144.0	156.4	162.0	128.3	134.1	111.5	48.0	52.1	54.0	72.7	72.0	67.4	27.3	28.0	32.6	267.2	257.2	206.5
11 p. m.	388.8	402.2	338.4	139.6	149.9	155.0	129.6	134.1	112.8	46.5	49.3	51.7	73.6	72.8	68.6	26.4	27.2	31.4	278.5	268.3	218.3
August 1:																					
1 a. m.	394.8	411.4	343.4	138.4	149.4	154.6	131.6	137.1	114.5	46.1	49.1	51.5	74.0	73.4	69.0	26.0	26.6	31.0	285.3	275.4	222.1
3 a. m.	387.8	427.1	344.8	132.3	149.6	149.0	129.3	142.4	114.9	44.1	49.2	49.0	74.6	74.1	69.8	25.4	25.9	30.2	293.1	285.5	231.4
5 a. m.	370.8	404.4	343.6	128.0	142.6	144.4	123.6	134.8	114.5	42.7	47.5	48.1	74.3	73.9	70.4	25.7	26.1	29.6	289.7	283.6	238.0
7 a. m.	371.8	390.2	336.8	129.2	143.8	144.2	123.9	130.1	112.3	43.1	47.9	48.1	74.2	73.1	70.0	25.8	26.9	30.0	287.8	271.3	233.6
9 a. m.	354.8	382.2	311.8	128.4	147.8	147.4	118.3	127.4	103.9	42.8	49.3	49.1	73.4	72.0	66.5	26.6	28.0	33.5	276.3	258.6	211.5
11 a. m.	331.0	373.0	310.6	134.8	146.4	153.4	110.3	124.3	103.5	44.9	48.8	51.1	71.1	71.8	66.9	28.9	28.2	33.1	245.5	254.8	202.5
1 p. m.	332.6	367.8	308.2	130.0	151.0	159.0	110.9	122.6	102.7	43.3	50.3	53.0	71.9	70.9	66.0	28.1	29.1	34.0	255.8	243.6	193.8
3 p. m.	317.8	373.5	299.2	133.8	154.8	169.8	106.6	124.5	93.1	44.6	51.6	56.6	70.4	70.7	63.8	29.6	29.3	36.2	237.5	241.3	176.2
5 p. m.	345.2	385.4	314.0	138.2	154.6	165.2	115.1	128.5	104.7	46.1	51.5	55.1	71.4	71.4	65.5	28.6	28.6	34.5	249.8	249.3	190.0
7 p. m.	356.6	391.0	325.8	134.4	150.8	163.2	118.9	130.3	108.6	44.8	50.3	54.4	72.6	72.2	66.2	27.4	27.8	33.8	265.3	259.3	199.6

JULY 20–21, 1916

July 20:																					
7 a. m.	371.0	.....	333.8	132.0	.....	139.2	123.7	.....	111.3	44.0	.....	46.6	73.7	.....	70.4	26.3	.....	29.6	281.1	.....	239.8
9 a. m.	362.2	.....	321.0	136.0	.....	141.6	120.7	.....	107.0	45.3	.....	47.2	72.7	.....	69.4	25.3	.....	30.6	267.5	.....	226.7
11 a. m.	358.6	.....	319.4	140.2	.....	145.6	119.5	.....	106.5	46.7	.....	48.5	71.9	.....	68.7	28.1	.....	31.3	256.1	.....	219.3
1 p. m.	353.0	.....	313.6	142.0	.....	149.8	117.7	.....	104.5	47.3	.....	49.9	71.3	.....	67.7	28.7	.....	32.3	248.5	.....	209.5
3 p. m.	352.0	.....	320.0	146.4	.....	157.6	117.3	.....	106.7	48.8	.....	52.5	70.9	.....	67.0	29.1	.....	33.0	240.4	.....	203.1
5 p. m.	358.4	.....	321.6	145.6	.....	162.6	119.5	.....	107.2	48.5	.....	54.2	71.1	.....	66.4	28.9	.....	33.6	246.2	.....	197.7
7 p. m.	365.4	.....	326.0	142.6	.....	158.4	121.8	.....	108.7	47.5	.....	52.8	71.9	.....	67.3	28.1	.....	32.7	255.9	.....	205.9
9 p. m.	381.9	.....	340.1	139.1	.....	156.0	127.3	.....	113.4	46.4	.....	52.0	73.3	.....	68.6	26.7	.....	31.4	274.3	.....	218.1
11 p. m.	380.0	.....	348.5	134.8	.....	150.8	126.7	.....	116.2	45.0	.....	50.3	75.3	.....	69.8	24.7	.....	30.2	282.1	.....	231.1
July 21:																					
1 a. m.	379.6	.....	348.2	128.9	.....	147.2	126.5	.....	116.1	43.0	.....	49.7	74.7	.....	70.3	25.3	.....	29.7	294.5	.....	236.3
3 a. m.	386.6	.....	362.6	123.6	.....	143.8	128.9	.....	120.9	41.2	.....	47.9	75.8	.....	71.9	24.2	.....	28.1	312.6	.....	252.2
5 a. m.	386.2	.....	358.6	125.0	.....	140.2	128.7	.....	119.5	41.7	.....	46.7	75.5	.....	71.9	24.5	.....	28.1	309.2	.....	255.6
7 a. m.	371.4	.....	349.8	132.6	.....	144.2	123.5	.....	116.5	44.2	.....	48.1	73.7	.....	70.8	26.3	.....	29.2	280.3	.....	242.3
9 a. m.	362.8	.....	339.6	132.6	.....	148.2	120.9	.....	113.2	44.2	.....	49.4	73.2	.....	69.6	26.8	.....	30.4	273.5	.....	229.1
11 a. m.	345.0	.....	329.4	133.6	.....	149.4	115.0	.....	109.8	44.5	.....	49.8	72.1	.....	68.8	27.9	.....	31.2	258.2	.....	220.5
1 p. m.	334.4	.....	318.8	135.0	.....	153.4	111.5	.....	106.3	45.0	.....	51.1	69.8	.....	67.5	30.2	.....	32.5	247.8	.....	207.9
3 p. m.	345.6	.....	327.8	131.6	.....	158.3	115.2	.....	109.3	43.7	.....	52.8	72.4	.....	67.4	27.6	.....	32.6	262.8	.....	207.8
5 p. m.	356.2	.....	334.4	139.0	.....	160.8	118.7	.....	111.5	46.3	.....	53.6	72.9	.....	67.5	28.1	.....	32.5	256.5	.....	207.9
7 p. m.	379.7	.....	351.8	135.8	.....	160.4	126.6	.....	117.3	45.3	.....	53.5	70.5	.....	68.7	29.5	.....	31.3	279.2	.....	219.1

JULY 26 AND 27, 1916

July 26:																					
7 a. m.	355.5	338.4	303.1	139.8	141.0	153.0	118.8	112.8	101.0	46.6	47.0	51.0	71.7	70.5	66.4	28.3	29.5	33.6	254.2	239.5	198.2
9 a. m.	342.8	333.8	302.8	143.8	146.2	157.2	114.3	111.3	100.9	47.9	48.7	52.4	70.4	69.5	65.8	29.6	30.5	34.2	238.3	228.4	192.5
11 a. m.	325.6	327.0	299.0	147.8	151.4	167.0	108.5	109.0	99.7	49.3	50.5	55.7	68.7	68.3	64.1	31.3	31.7	35.9	220.3	216.2	179.2
1 p. m.	322.6	326.6	294.0	146.2	153.2	170.4	107.5	108.9	98.0	48.7	51.1	56.8	68.8	68.0	63.3	31.2	32.0	36.7	220.5	213.1	172.5
3 p. m.	326.0	332.2	296.0	147.4	156.2	179.4	108.7	110.7	98.7	49.1	52.1	59.8	68.8	66.8	62.2	31.2	33.2	37.8	221.2	212.6	165.2
5 p. m.	336.0	338.2	303.4	147.0	161.2	181.6	112.0	112.7	101.1	49.0	53.7	60.5	69.5	67.7	62.5	30.5	32.3	37.5	228.5	209.8	167.2
7 p. m.	354.0	352.3	315.8	149.0	160.0	176.2	118.0	117.4	105.3	49.7	53.3	58.7	70.3	68.7	64.2	29.7	31.3	35.8	237.6	220.2	179.3
9 p. m.	361.0	366.0	323.6	146.0	154.7	169.1	120.3	122.0	107.9	48.7	51.2	56.4	71.2	70.2	65.6	28.8	29.8	34.4	247.2	236.5	191.2
11 p. m.	370.6	375.8	330.5	138.6	147.5	161.1	123.5	125.3	110.2	46.2	49.2	53.7	72.7	71.8	67.2	27.3	28.2	32.8	267.2	254.5	205.2
July 27:																					
1 a. m.	379.4	383.2	338.0	136.8	145.8	164.6	126.5	127.7	112.7	45.6	48.6	54.9	73.4	72.4	67.2	26.6	27.6	32.8	277.5	262.8	205.8
3 a. m.	379.6	389.0	340.4	136.0	144.9	162.0	126.5	129.7	113.5	45.3	48.3	54.0	73.6	72.8	67.5	26.4	27.6	32.5	278.8	268.5	210.3
5 a. m.	375.8	391.4	350.6	134.4	136.2	155.6	125.3	130.5	116.9	44.8	45.4	51.9	73.6	74.1	69.2	26.4	25.9	30.8	279.6	287.2	225.3
7 a. m.	367.9	383.6	348.8	136.1	140.8	159.6	122.6	127.9	116.3	45.4	46.9	53.2	72.9	73.1	68.6	27.1	26.9	31.4	270.2	272.4	218.2
9 a. m.	351.4	372.9	329.3	138.4	143.7	165.7	117.1	124.3	109.8	46.1	47.9	55.2	71.7	72.1	66.5	28.3	27.9	33.5	254.0	259.4	198.8
11 a. m.	341.6	356.4	322.0	136.9	151.5	168.0	113.5	118.8	107.3	45.3	50.5	56.0	71.5	70.1	65.5	28.5	29.9	34.5	251.2	235.3	191.8
1 p. m.	322.8	353.0	315.2	142.8	147.1	173.5	107.6	117.7	105.1	47.6	49.0	58.5	69.3	70.5	64.2	30.7	29.5	35.8	226.2	240.2	179.8
3 p. m.	336.8	365.6	324.7	134.4	151.5	176.2	112.3	121.9	108.2	44.8	50.5	58.7	71.4	70.7	64.8	28.6	29.3	35.2	250.5	241.3	184.2
5 p. m.	365.0	381.8	331.3	132.9	147.6	183.1	121.7	127.3	110.4	44.3	49.2	61.0	73.3	72.1	64.4	26.7	27.9	35.6	274.8	258.4	181.0
7 p. m.	367.7	392.8	340.3	136.1	149.6	175.9	122.6	130.9	113.4	45.4	49.9	58.6	72.9	72.4	65.9	27.1	27.6	34.1	270.2	262.2	193.7

TABLE III.—*Variation of the water and dry matter in the leaves of Pride of Saline corn, Blackhull kafir, and Dwarf milo at Garden City, Kans.*—Contd.

AUGUST 1 AND 2, 1916.

Period ending—	Water in 30 samples.			Dry matter in 30 samples.			Water per square meter of leaf.			Dry matter per square meter of leaf.			Percentage of water, wet basis.			Percentage of dry matter.			Percentage of water, dry basis.		
	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.	Corn.	Kafir.	Milo.
August 1:	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*									
7 a. m.	369.9	.....	314.2	147.3	.....	152.4	123.3	.....	104.7	49.1	.....	50.8	71.5	.....	67.5	28.5	.....	32.5	250.8	.....	206.2
9 a. m.	355.7	.....	305.9	149.9	.....	160.2	118.6	.....	102.0	50.0	.....	53.4	70.3	.....	65.6	29.7	.....	34.4	238.2	.....	190.7
11 a. m.	337.3	.....	299.6	154.3	.....	167.0	112.4	.....	99.9	51.4	.....	55.7	68.6	.....	64.2	31.4	.....	35.8	218.8	.....	179.2
1 p. m.	320.6	.....	293.6	153.8	.....	175.0	106.9	.....	97.9	51.3	.....	58.3	67.5	.....	62.6	32.5	.....	37.4	208.4	.....	167.5
3 p. m.	312.7	.....	297.0	154.2	.....	183.1	104.2	.....	99.0	51.4	.....	61.0	66.9	.....	61.7	33.1	.....	38.3	202.8	.....	162.1
5 p. m.	345.1	.....	306.0	155.0	.....	184.5	115.0	.....	102.0	51.7	.....	61.5	69.0	.....	62.4	31.0	.....	37.6	222.9	.....	165.9
7 p. m.	368.0	.....	319.7	153.0	.....	180.7	122.7	.....	106.6	51.0	.....	60.2	70.6	.....	62.9	29.4	.....	37.1	240.5	.....	176.7
9 p. m.	371.0	.....	326.0	150.5	.....	174.1	123.7	.....	108.7	50.2	.....	58.0	71.1	.....	65.1	28.9	.....	34.9	246.6	.....	187.2
11 p. m.	385.8	.....	338.0	147.4	.....	173.4	128.6	.....	112.7	49.1	.....	57.8	72.3	.....	66.1	27.7	.....	33.9	261.7	.....	195.0
August 2:																					
1 a. m.	393.8	.....	349.7	143.0	.....	166.8	131.3	.....	116.6	47.7	.....	55.6	73.3	.....	67.7	26.7	.....	32.3	275.2	.....	209.5
3 a. m.	387.7	.....	346.8	141.9	.....	164.8	129.2	.....	115.6	47.3	.....	54.9	73.2	.....	67.8	26.8	.....	32.2	273.3	.....	210.3
5 a. m.	374.6	.....	345.0	139.8	.....	156.4	124.9	.....	115.0	46.6	.....	52.1	72.8	.....	68.8	27.2	.....	31.2	267.9	.....	220.8
7 a. m.	381.7	.....	352.3	141.4	.....	162.6	127.2	.....	117.4	47.1	.....	54.2	72.9	.....	68.4	27.1	.....	31.6	269.5	.....	216.8
9 a. m.	358.4	.....	337.2	139.4	.....	164.8	119.5	.....	112.4	46.5	.....	54.9	72.0	.....	67.2	28.0	.....	32.8	258.3	.....	204.9
11 a. m.	346.4	.....	329.4	151.0	.....	180.0	115.5	.....	109.8	50.3	.....	60.0	69.7	.....	64.7	30.3	.....	35.3	229.5	.....	183.0
1 p. m.	346.2	.....	329.9	154.4	.....	187.2	115.4	.....	110.0	51.5	.....	62.4	69.2	.....	63.8	30.8	.....	36.2	224.3	.....	176.1
3 p. m.	323.4	.....	320.0	140.8	.....	185.0	107.8	.....	106.7	46.9	.....	61.7	69.7	.....	63.4	30.3	.....	36.6	229.8	.....	172.8
5 p. m.	345.6	.....	338.8	149.0	.....	188.0	115.2	.....	112.9	49.7	.....	62.7	69.9	.....	64.3	30.1	.....	35.7	231.9	.....	180.1
7 p. m.	.....	.....	340.6	.....	.....	185.0	.....	.....	113.5	.....	.....	61.7	.....	.....	64.8	.....	.....	35.2	.....	.....	184.0

AUGUST 10 AND 11, 1916.

August 10:																					
7 a. m.	348.3	371.4	303.5	166.2	163.2	181.2	116.1	123.8	101.2	55.4	54.4	60.4	67.7	69.4	62.6	32.3	30.6	37.4	209.5	227.5	167.5
9 a. m.	343.4	368.0	307.1	167.6	165.8	186.8	114.5	122.7	102.4	55.9	55.3	62.3	67.2	69.0	62.4	32.8	31.0	37.6	204.8	221.9	164.3
11 a. m.	332.1	348.0	298.0	166.8	168.0	196.0	110.7	116.0	99.3	55.6	56.0	65.3	66.6	67.4	60.3	33.4	32.6	39.7	199.0	207.2	152.0
1 p. m.	316.8	339.4	295.8	165.8	164.0	195.2	105.6	113.1	98.6	55.3	54.7	65.1	65.6	67.4	60.3	34.4	32.6	39.7	191.0	206.9	151.5
3 p. m.	315.4	338.3	294.5	167.8	170.2	201.4	105.1	112.8	98.2	55.9	56.7	67.1	65.3	66.5	59.4	34.7	33.5	40.6	188.0	198.7	146.3
5 p. m.	322.9	349.2	298.3	172.4	169.2	203.2	107.6	116.4	99.4	57.5	56.4	67.7	65.2	67.4	59.5	34.8	32.6	40.5	187.3	206.4	146.7
7 p. m.	343.0	379.9	312.3	168.4	170.2	196.0	114.3	126.6	104.1	56.1	56.7	65.3	67.1	69.1	61.4	32.9	30.9	38.6	203.7	223.2	159.4
9 p. m.	359.1	389.5	314.3	166.2	168.0	190.7	119.7	129.8	104.8	55.4	56.0	63.6	68.4	69.9	62.2	31.6	30.1	37.8	216.2	231.7	164.7
11 p. m.	364.1	393.9	334.1	162.6	165.4	194.0	121.4	131.3	111.4	54.2	55.1	64.7	69.1	70.5	63.3	30.9	29.5	36.7	224.0	238.1	167.1

August 11:																							
1 a. m.	357.5	392.0	336.2	157.6	164.3	189.1	119.2	130.7	110.1	53.5	54.8	63.0	69.4	70.5	63.6	30.6	29.5	36.4	226.7	238.5	174.6
3 a. m.	358.6	393.5	331.6	159.4	166.0	185.0	119.5	131.2	110.5	53.1	53.3	61.7	69.2	71.1	64.2	30.8	28.9	35.8	225.0	246.0	179.3
5 a. m.	361.4	395.4	332.6	155.5	157.9	182.6	120.5	131.8	110.9	51.8	52.6	60.9	69.9	71.5	64.8	30.1	28.5	35.2	232.4	250.4	182.2
9 a. m.	354.8	395.5	334.8	159.0	166.9	187.5	118.3	131.8	111.6	53.0	53.6	62.5	69.1	70.9	64.1	30.9	29.1	35.9	223.0	245.7	178.5
11 a. m.	347.0	381.0	324.6	166.5	164.5	195.0	115.7	127.0	108.2	53.5	54.8	63.0	69.8	69.8	62.5	31.6	30.2	37.5	216.2	231.5	166.4
1 p. m.	343.4	374.4	319.2	163.1	169.3	200.8	114.5	124.5	106.4	54.4	56.4	66.9	67.8	68.9	61.4	31.2	31.1	38.6	210.5	221.3	158.9
3 p. m.	326.4	356.1	316.1	162.6	168.0	208.3	108.8	118.7	105.4	54.2	56.0	69.4	66.7	67.9	60.3	33.3	32.1	39.7	200.6	212.0	151.7
5 p. m.	319.2	353.7	309.3	169.6	169.8	213.3	106.4	117.9	103.1	56.5	56.6	71.1	65.3	67.7	59.2	34.3	33.3	40.8	188.2	208.3	145.0
7 p. m.	340.2	383.4	309.0	165.6	164.2	209.1	113.4	127.8	109.7	55.2	54.7	69.7	67.3	70.1	61.2	32.7	29.9	38.8	200.5	231.5	157.4
	351.3	394.2	341.6	162.9	165.1	209.0	117.1	131.4	113.9	54.3	55.0	69.7	68.3	70.5	62.0	31.7	29.5	38.0	215.7	238.8	163.4

TABLE IV.—*Summary of the variation of the water content of the leaves of corn, kafir, and milo during the years 1914, 1915, and 1916, at Garden City, Kans.*

Time.	Plant.	Loss.			Gain.			Net gain or loss.	
		Number of cases of loss.	Average loss of leaf water per square meter of leaf.	Average percentage of loss based on leaf water at beginning of period.	Number of cases of gain.	Average gain of leaf water per square meter of leaf.	Average per centage of loss based on leaf water at beginning of period.	Per square meter of leaf.	Percentage based on leaf water at beginning of period.
			Gm.			*Gm.*		*Gm.*	
7 a. m to 9 a. m.	Corn	21	4.1	3.5	0	0	0	[a] 4.1	[a] 3.5
	Kafir	15	3.3	2.8	1	3.8	3.2	[a] 3.0	[a] 2.5
	Milo	18	4.2	4.0	3	1.3	1.3	[a] 3.6	[a] 3.4
9 a. m. to 11 a. m.	Corn	18	4.8	4.2	2	2.5	2.2	[a] 4.1	[a] 3.8
	Kafir	16	3.9	3.4	1	1.3	1.0	[a] 3.7	[a] 3.4
	Milo	20	2.2	2.1	1	5.2	5.6	[a] 1.9	[a] 1.8
11 a. m. to 1 p. m.	Corn	15	3.7	3.4	6	2.9	2.4	[a] 2.5	[a] 2.2
	Kafir	14	3.1	2.8	3	4.2	3.6	[a] 2.5	[a] 2.2
	Milo	13	1.9	1.9	7	1.7	1.6	[a] 1.1	[a] 1.1
1 p. m. to 3 p. m.	Corn	10	3.1	2.8	10	2.5	2.2	[a] 1.8	[a] 1.6
	Kafir	4	2.5	2.1	13	3.1	2.7	[b] 2.0	[b] 1.7
	Milo	11	3.3	3.3	10	2.6	2.5	[a] 1.7	[a] 1.6
3 p. m. to 5 p. m.	Corn	4	2.7	2.3	17	5.7	4.9	[b] 4.6	[b] 4.0
	Kafir	0	0	0	17	4.3	3.6	[b] 4.3	[b] 3.6
	Milo	4	4.1	4.2	17	3.9	3.7	[b] 3.2	[b] 3.0

[a] Loss. [b] Gain.

VARIATION OF THE WATER IN THE LEAVES

1. WATER PER SQUARE METER OF LEAF

The average water content per square meter of leaf for the day and night periods was 123.2 gm. for corn, 126.3 gm. for kafir, and 111.4 gm. for milo. The amount of water in the leaves of milo was found to be strikingly lower than that of either corn or kafir leaves at all times of the day and night. The amount of water in the leaves of kafir for all the periods averaged slightly higher than that of corn. In some experiments the corn leaves showed a greater amount of water than the kafir, while in other experiments the kafir leaves had the higher amount. The leaves of kafir that were used in one experiment in 1914, and in two experiments in 1916, were, however, a few weeks younger than the corn leaves and consequently had more water per unit of area, so that, on the whole, there appears to be little, if any, difference in the average water content of the leaves of corn and Blackhull kafir at the same stage of development.

The water content of the leaves of corn, kafir, and milo averaged 118.5, 120.0, and 107.0 gm. per square meter of leaf, respectively, for the day periods, and, taken in the same order, 127.9, and 132.7, and 115.5 gm. for the night periods. This made an average difference between the day

and night of 9.4, 12.7, and 8.5 gm. of water per square meter of leaf, respectively, for corn, kafir, and milo.

For the 22 days the minimum amount of water in the corn leaves was reached 4 times at 11 a. m.,[1] 7 times at 1 p. m., 10 times at 3 p. m., and once at 5 p. m., while in the same number of periods the milo leaves reached their minimum amount of water twice at 11 a. m., 10 times at 1 p. m., 9 times at 3 p. m., and once at 9 a. m. For 18 days the kafir leaves showed the minimum amount of water twice at 11 a. m., 13 times at 1 p. m., and 3 times at 3 p. m. The average difference between the maximum and minimum amounts of water in the leaves during the day was 13.8, 8.4, and 7.8 gm. per square meter of leaf surface, respectively, for corn, kafir, and milo. The maximum evaporation as measured by the Livingston porous-cup atmometers occurred 18 times between 2 and 3 p. m. and four times between 3 and 5 p. m. The evaporation as represented in figures 1 to 10 is plotted for 2-hour periods, so that the hour of maximum evaporation may not be shown by the curves. The minimum amount of water in the leaves during the day occurred 7 times for corn, twice for kafir, and 7 times for milo at the same time as the maximum evaporation. In 9 cases for corn, 12 for kafir, and 10 for milo the minimum amount of water in the leaves was reached two hours before maximum evaporation, while in 5 cases for corn, 4 for kafir, and 4 for milo the lowest water content of the leaves occurred four hours before the maximum evaporation. Thus, in two-thirds of the cases of corn and milo and in nine-tenths of the cases of kafir, the minimum amount of water in the leaves occurred under the condition of these experiments from two to four hours earlier than did the maximum evaporation, as shown by the Livingston porous-cup atmometer.

During the night the maximum water content of the corn leaves was reached 3 times at 11 p. m., 3 times at 1 a. m., twice at 3 a. m., once at 9 p. m., and twice at 5 a. m. The leaves of kafir showed the greatest amount of water once at 11 p. m., 5 times at 1 a. m., and 3 times at 5 a. m., while the milo leaves reached their maximum water content once at 11 p. m., 4 times at 1 a. m., 3 times at 3 a. m., twice at 5 a. m., and once at 7 a. m. The lowest evaporation for the 11 night periods occurred 9 times between 4 and 5 a. m. and twice between 2 and 3 a. m. The average difference between the minimum and maximum water content of the leaves per square meter of surface during the night was 10.3 gm. for corn, 16 gm. for kafir, and 13.1 gm. for milo. The difference between the average minimum water content of the leaves during the day and the average maximum water content during the night was 23.8, 25.9, and 21.7 gm. per square meter of leaf for corn, kafir, and milo, respectively. It is worthy of note that in all the night experiments abundant guttation

[1] In the following discussion the maximum or minimum amount of water or dry matter in the leaves is considered as occurring at the close of a 2-hour period, but, as a matter of fact, it might have occurred at any time during the two preceding hours.

was observed on the leaves of both milo and kafir, while in only two observations was it noticeable on the leaves of corn, and then it appeared in only very small amounts.

II. PERCENTAGE OF WATER

The average percentage of water for both the days and nights was 70.7 for corn, 69.9 for kafir, and 65.5 for milo. The average percentage of water in the leaves during the 22 days was found to be 71.3, 70.3, and 65.8 for corn, kafir, and milo, respectively. Taken in the same order, the average percentage of water during the 10 night periods was 70.2 69.6, and 65.3, a difference between the night and day of 1.1, 0.7, and 0.5 per cent, respectively, for the corn, kafir, and milo. The minimum percentage of water in the leaves during the day occurred from 11 a. m. to 5 p. m. In most cases the minimum percentage was reached between 1 and 3 p. m. In almost one-third of the cases the percentage of water varied little, if any, from 11 a. m. to 3 p. m. The minimum percentage of water in the leaves occurred at 3 p. m. more frequently than at any other period. The average difference between the maximum and minimum percentage of water in the leaves during the day was 3.5 for corn, 3.2 for kafir, and 4.5 for milo.

The maximum percentage of water in the leaves of the corn during 10 nights occurred 5 times at 5 a. m., 3 times at 3 a. m., and twice at 1 a. m. For the same number of periods the milo leaves reached their maximum percentage of water 7 times at 5 a. m., once at 3 a. m., and twice at 1 a. m. In 8 night periods the kafir leaves showed the greatest percentage of water 5 times at 5 a. m., once at 3 a. m., and twice at 1 a. m. The average difference between the minimum and maximum percentage of water in the leaves during the night was, respectively, 3.0, 4.2, and 4.7 for corn, kafir, and milo.

The average difference between the maximum percentage of water in the leaves at night and the minimum percentage of water during the day was found to be 5.4 for corn, 5.9 for kafir, and 6.0 for milo.

III. PERCENTAGE OF WATER (DRY BASIS)

For all the day and night periods the average percentage of water in the leaves on a dry basis; or, in other words, the ratio of the weight of water to the weight of dry matter was 251.2 for corn, 234.5 for kafir, and 195.1 for milo. The average percentage of water on this basis for all the day periods was 240.0, 218.2, and 183.1, respectively, for corn, kafir, and milo, while, in the same order, the average percentage during the 10 nights was 256.8, 235.9, and 197.0. This made an average difference between the maximum and minimum percentage of water in the leaves during the night and day of 16.8 for corn, 17.7 for kafir, and 13.9 for milo. The average variation of the percentage of water on a dry basis during the daylight hours was 39.5 for corn, 31.1 for kafir,

and 35.9 for milo. The minimum percentage of water on this basis occurred for the three plants for the most part from 1 to 5 p. m. The maximum percentage of water in the leaves of corn occurred, during 11 nights, 7 times at 5 a. m., twice at 3 a. m., and twice at 1 a. m. The maximum percentage of water in the leaves of milo with but one exception was found to be at 5 a. m. In 9 nightly observations of kafir leaves the maximum percentage of water occurred 6 times at 5 a. m., once at 3 a. m., and twice at 1 a. m. The average difference between the minimum and maximum percentage of leaf water during the night was 37.5 for corn, 47.5 for kafir, and 40.0 for milo. The average range between the maximum percentage of water in the leaves during the night and the minimum percentage during the day was 67.8, 67.2, and 51.2 for corn, kafir, and milo, respectively.

VARIATION OF THE DRY MATTER

1. DRY MATTER PER SQUARE METER OF LEAF

The dry weight of a given area of milo leaf was always found to be greater than an equal area of either corn or kafir leaves of the same age. The average dry weight of a square meter of leaf for all the observations made during these experiments was found to be 48.2 gm. for corn, 52.5 gm. for kafir, and 56.2 gm. for milo. The average amounts of dry matter per square meter of leaf during 17 days was 49.1, 54.1, and 57.4 gm., respectively, for corn, kafir, and milo, while, taken in the same order, the average dry weight of the same area of leaves was 48.4, 53.4, and 56.9 gm. This makes an average difference in dry weight of a square meter of leaf between the day and night of 0.7 gm. for corn and kafir and 0.5 gm. for milo. These differences are much less than one would expect; but a glance at the dry-matter curves shows that in most cases there was a gradual increase in dry matter from 5 a. m. till 3 to 5 p. m., and that there was little depletion of dry matter before 7 p. m. After that there was in most cases a gradual depletion of dry matter in the leaves until 5 a. m. Since there was a gradual increase of dry matter during the day and a corresponding decrease during the night, the average leaf weight for the day and the night was practically the same.

The maximum amount of dry matter in the leaves of corn for 21 days occurred 4 times at 1 p. m., 5 times at 3 p. m., 11 times at 5 p. m., and once at 7 p. m. The dry matter of the leaves of milo for the same number of periods reached a maximum 6 times at 3 p. m., 14 times at 5 p. m., and once at 7 p. m. In 17 day periods the leaves of kafir reached their maximum amount of dry matter 7 times at 3 p. m., 9 times at 5 p. m., and once at 7 p. m. On August 16, 1916, the dry matter in the leaves of all three plants never increased over what it was at 7 a. m. It is seen from the figures quoted above that the maximum amount of dry matter

in the leaves of the three plants occurs in the most cases between 2 and 5 p. m. The average difference between the minimum and maximum amount of dry matter in the leaves during the day was 4.0, 4.8, and 8.0 gm. for corn, kafir, and milo, respectively.

The minimum amount of dry matter in the leaves of corn during 10 nights from 7 p. m. to 7 a. m. occurred 8 times at 5 a. m., once at midnight, and once at 3 a. m., while the leaves of milo in the same number of experiments reached their minimum dry-matter content 7 times at 5 a. m., twice at 7 a. m., and once at 7 p. m. During the 8 nights that the leaves of kafir were examined, the minimum amount of dry matter occurred at 5 a. m. in all cases. Sunrise occurred about 5 a. m. at the time of these experiments.

The average difference between the maximum and minimum amount of dry matter per square meter of leaf during the night periods was 5.3, 5.2 and 6.3 gm., respectively, for the corn, kafir, and milo.

The maximum amount of dry matter in the leaves of corn during the night occurred 7 times at 7 p. m., twice at 9 p. m., and once at 11 p. m. The leaves of milo during the same number of periods reached the maximum amount of dry matter 7 times at 7 p. m., twice at 11 p. m., and once at 9 p. m. In 8 night experiments with kafir the dry matter in the leaves was the highest 5 times at 7 p. m., twice at 9 p. m., and once at 11 p. m. The average variation of dry matter from the minimum amount in the leaves at night to the maximum amount in the leaves during the day was 6.2, 6.0, and 7.7 gm. per square meter of leaf for corn, kafir, and milo, respectively.

Several cases were noted where a marked increase in the dry matter of the leaves occurred for one or more 2-hour periods during the night. On August 10, 1914, the dry matter decreased in the leaves of all three of the plants from 5 to 9 p. m. During the next 2-hour period the dry matter in the leaves of corn increased from 46.9 to 48.6 gm. per square meter of leaf, while in the same time an equal area of kafir leaf increased in dry weight from 50.9 to 51.9 gm. From 9 p. m. to 11 p. m. the dry matter in the leaves of milo increased 1.6 gm. per square meter of leaf and showed no signs of depletion until 1 a. m. On August 15, 1914, the dry matter in the leaves increased 3.5, 1.7, and 2.8 gm. per square meter of leaf, respectively, for corn, kafir, and milo between 7 and 9 p. m. On August 25, 1914, the dry matter in the leaves of corn dropped from 54.3 gm. per square meter at 5 p. m. to 51.9 gm. at 7 p. m., and then increased the next two periods to 53.7 gm. at 11 p. m. The kafir leaves decreased in dry matter per square meter from 60.4 gm. at 5 p. m. to 58.7 gm. at 7 p. m., and then gradually increased during the next two periods to 61.3 gm. at 11 p. m. After 11 p. m. the dry matter in the leaves of both corn and kafir began to decrease. The dry matter in the milo leaves decreased 2.6 gm. per square meter of leaf surface from 5 to 7 p. m. During

the next two hours it increased 6.7 gm., then decreased 2.2 gm. until 11 p. m., when the amount of dry matter remained constant until 1 a. m., after which a gradual depletion began to occur. (See Table III, Aug. 10–26, 1914, and fig. 3, 4, and 5.)

II. PERCENTAGE OF DRY MATTER

The average percentage of dry matter in the leaves during both the day and night was found to be 28.7 for corn, 30.1 for kafir, and 34.3 for milo. The average percentage of dry matter in the leaves during the day periods was 29.0, 30.5, and 34.7, respectively, for corn, kafir, and milo, while taken in the same order the average percentage of dry matter during the 10 night periods was 28.3, 29.8, and 33.9. This made an average difference in the percentage of dry matter between the day and night of approximately 0.7 for all three plants. With but few exceptions the maximum percentage of dry matter in the leaves of all three plants occurred between 11 a. m. and 3 p. m. The average difference between the maximum and minimum percentage of dry matter during the day was 3.5 for corn, 3.3 for kafir, and 4.6 for milo. The minimum percentage of dry matter in the leaves of corn during the night occurred twice at 1 a. m., 3 times at 3 a. m., and 5 times at 5 a. m. In all the 10 night experiments with milo the minimum percentage of dry matter occurred at 5 a. m. In 8 night experiments with kafir the minimum percentage of dry matter was in 2 cases at 1 a. m. and in 6 cases at 5 a. m. The average difference between the maximum and minimum percentage of dry matter during the night was 3.0, 4.2, and 4.8 for corn, kafir, and milo, respectively. The average difference between the maximum percentage of dry matter during the day and the minimum percentage during the night was 5.1 for corn, 5.9 for kafir, and 6.0 for milo.

For the purpose of comparison, the results have been obtained by other investigators in their study of the daily variation of the water content of leaves are briefly reviewed here. Lloyd[1] found that the percentage of water on a dry basis in the leaves of *Fouquieria splendens* varied from 225 to 300 as extreme limits between day and night and that the diminution of water in the leaves began at daybreak and continued until some time between noon and 4 p. m. After that time the water in the leaves increased till approximately 4 a. m. In experiments with the cotton plant, Lloyd[2] found that the leaf water stated in percentage of dry weight varied under usual conditions between 318 and 220 per cent and that the minimum leaf water content was reached at 2 p. m. or thereabouts. The amount of loss of leaf water when thus determined was from 7 to 15 per cent of the initial amount at sunrise.

[1] LLOYD, F. E. THE RELATION OF TRANSPIRATION AND STOMATAL MOVEMENTS TO THE WATER CONTENT OF THE LEAVES IN FOUQUIERIA SPLENDENS. *In* Plant World, v. 15, no. 1, p. 1–14, 1 fig. 1912.

[2] ———. LEAF WATER AND STOMATAL MOVEMENT IN GOSSYPIUM AND A METHOD OF DIRECT VISUAL OBSERVATION OF STOMATA IN SITU. *In* Bul. Torrey Bot. Club, v. 40, no. 1, p. 1–26, 3 fig. 1913.

Livingston and Brown [1] investigated the water content of the leaves of numerous plants growing in the vicinity of Tucson, Ariz., and found that the time of the minimum water content of the leaves fell within an hour or two of the maximum evaporation rate. The minimum moisture content of the leaves of most of these plants, estimated on both a dry and a wet basis, occurred between 1 and 5 p. m.

GENERAL CONCLUSIONS

VARIATION OF THE WATER CONTENT

The leaves of milo contained less water at all times than the leaves of either corn or kafir at the same stage of development. The average water content per square meter of leaf for all the observations made was 111.4 gm. for milo, 123.2 gm. for corn, and 126.3 gm. for kafir. The amount of water in the leaves of corn and kafir was practically the same at like stages of growth. The small difference between the average amount of water in the leaves of kafir as compared with those of corn is due to the fact that in one experiment in 1914 and in two experiments in 1916 the leaves of the kafir were about 10 days younger than those of the corn and, as a consequence, contained a greater amount of water.

Under the conditions of these experiments, the leaves of corn in most cases were wilted during the greater portion of the day. The first signs of wilting were most generally observed between 9 a. m. and 10 a. m., and in most cases no visible wilting could be observed after 4 p. m. The kafir leaves wilted during the day, but not to the extent that the leaves of the corn did, while the milo leaves showed little or no signs of wilting. Under these conditions the average range between the maximum and minimum amount of water per square meter of leaf during the 2-hour periods from 7 a. m. to 7 p. m. was 13.8 gm. for corn, 8.4 gm. for kafir, and 7.8 gm. for milo.

Table IV shows the average gain or loss of leaf water during each 2-hour period of the day from 7 a. m. to 5 p. m. for the experiments conducted in 1914, 1915, and 1916. The average gain or loss for each period is expressed in grams per square meter of leaf and in percentage based on the water in the leaf at the beginning of the 2-hour period.

The time of the day when the loss of leaf water ceases and an increase in its amount begins depends upon the aerial conditions under which the experiment is conducted. Under the conditions of these experiments the leaves of the three plants, with but few exceptions, showed a decrease in the water content between 7 and 11 a. m. In one-third of the observations for corn and milo and in one-fifth of the observations for

[1] LIVINGSTON, B. E., and BROWN, W. H. RELATION OF THE DAILY MARCH OF TRANSPIRATION TO VARIATIONS IN THE WATER CONTENT OF FOLIAGE LEAVES. *In* Bot. Gaz., v. 53, no. 4, p. 309-330, pl. 24-25. 1912.

kafir the leaves showed a gain in their leaf water between 11 a. m. and 1 p. m. From 1 to 3 p. m. the leaves gained in the amount of their leaf water in one-half of the observations of corn and milo and in three-fourths of the observations of kafir, while from 3 to 5 p. m. the leaves of kafir showed a gain in water in all cases. In only four cases did the leaves of milo and corn show a loss of water during this period. In the following discussion the cases of the loss of leaf water only will be considered.

The average loss of leaf water per square meter of leaf, between 7 and 9 a. m. was 4.1 gm. for corn, 3.3 gm. for kafir, and 4.2 gm. for milo, while the percentage of loss based on the amount of water in the leaf at the beginning of the period was 3.5, 2.8, and 4.0, respectively, for corn kafir, and milo. During this period the water in the leaves of corn and milo decreased in like amount, but the percentage loss was higher for milo than for corn. The average loss of the leaf water of the kafir during this period was the least for the three plants, both in percentage and in actual amount.

From 9 to 11 a. m. the water content of the leaves per square meter of leaf decreased 4.8, 3.9, and 2.2 gm., respectively, for corn, kafir, and milo, from what it was at the close of the previous period, while the percentage of loss was 4.2 for corn, 3.4 for kafir, and 2.1 for milo. The rate of water loss during this period thus increased markedly for corn and kafir, both in percentage and in actual amount, while the loss for milo was only one-half of what it was from 7 to 9 a. m. From 11 a. m. to 1 p. m., the decrease in the amount of leaf water for each square meter of leaf was 3.7 gm. for corn, 3.1 gm. for kafir, and 1.9 gm. for milo, while, taken in the same order, the percentage loss was 3.4, 2.8, and 1.9. The rate of loss during this period decreased markedly for corn and kafir, while the change in the rate of milo was very slight. From 1 to 3 p. m. the average loss of leaf water was 3.1, 2.5, and 3.3 gm. for each square meter of leaf for corn, kafir, and milo, respectively, while the percentage loss was 2.8 for corn, 2.1 for kafir, and 3.3 for milo. While the rate of the loss of water in the leaves of corn and kafir continued to decrease, the loss in the leaves of milo showed a marked increase, both in percentage and actual amount, over what it was at the close of the previous period.

A consideration of the loss of the leaf water during the day shows that from 7 to 9 a. m. the rate of loss was practically the same for corn and milo and the least for kafir. From 9 to 11 a. m., as the aerial conditions became more severe, the rate of loss increased for corn and kafir, but decreased almost one-half for milo. During the next two hours the rate of loss decreased for all three plants, but the rate of loss was approximately twice as great for corn and kafir as for milo. From 1 to 3 p. m. the rate of loss continued to decrease, while the rate of loss of milo increased over 1 per cent. These results seem to indicate that the

absorption of water by the milo from the soil and its translocation to leaves was proceeding more rapidly in proportion to the loss of water from the plant than in the case of either corn or kafir. The fact that the leaves of milo seldom wilted during the day also indicated that fact. The wilting of the leaves of milo in contrast to either the corn or kafir usually could not be observed until much later in the day. The increase in the rate of loss of leaf water in the milo from 1 to 3 p. m. would indicate that the rate of absorption of water from the soil during that period was less than the loss by evaporation from the leaves.

VARIATION OF THE DRY MATTER

The amount of dry matter in the leaves of milo was at all times greater than in the leaves of corn or kafir of the same age. If we take the average weight of a square meter of corn leaf as 1, the average weight of an equal area of leaf would be 1.08 for kafir and 1.16 for milo. These differences in weight could be due either to the more compact arrangement of the cells or to a difference in the thickness of the leaves of the three plants or to both of these factors.

The average difference between the maximum and minimum amount of dry matter in the leaves during the day from 7 a. m. to 7 p. m. was 4 gm. for corn, 4.8 gm. for kafir, and 8.0 gm. for milo. Table V shows the rate of increase in dry matter for corn, kafir, and milo in grams per square meter of leaf for each of the 2-hour periods during the day, from 7 a. m. to 5 p. m. From 7 to 9 a. m. the rate of increase in dry matter for each square meter of leaf was 2.2 gm. for corn, 1.7 gm. for kafir, and 1.3 gm. for milo. From 9 to 11 a. m. the increase of dry matter on the same basis was 1.1, 1.2, and 1.5 gm. for corn, kafir, and milo, respectively, while from 11 a. m. to 1 p. m. the increase was 0.8 gm. for corn, 0.7 gm. for kafir, and 2.2 gm. for milo. From 1 to 3 p. m. the rate of increase was 0.7 gm. for corn, 1.3 gm. for kafir, and 2 gm. for milo, while from 3 to 5 p. m. the increase of dry matter was 0.8, 0.7, and 0.8 gm. per square meter of leaf surface, respectively, for corn, kafir, and milo. The greatest rate of increase of dry matter in the corn leaves occurred from 7 to 9 a. m. During the next 2-hour period the rate had fallen one-half. The rate continued to decrease until 3 p. m., when there was a slight increase. The rate of increase of dry matter in the leaves of milo rose gradually from 7 a. m. until 1 p. m. and then remained constant until 3 p. m., when it began to decrease. The results with the leaves of kafir were not so marked. There was a noticeable falling of the rate of increase of dry matter from 9 a. m. to 1 p. m., and then a slight increase in the rate till 3 p. m.

TABLE V.—*Average rate of increase of the dry matter for each square meter of leaf for corn, kafir, and milo during each 2-hour period of the day*

Plant.	A. M.			P. M.	
	7–9	9–11	11–1	1–3	3–5
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Corn	2.2	1.1	0.8	0.7	0.8
Kafir	1.7	1.2	.7	1.2	.7
Milo	1.3	1.5	2.2	2.0	.8

Two explanations are possible for these results. The milo plant either manufactures food in the leaves more rapidly than the corn or kafir or the rate of translocation is higher in the latter plants. In most cases, under the conditions of these experiments, the leaves of corn were badly wilted during the greater portion of the day. The kafir leaves also wilted, but not to the extent of the corn, while the leaves of milo very seldom showed signs of wilting. The smaller increase in dry matter in the leaves of corn and kafir during the greater portion of the day in comparison to the leaves of milo is evidently due to the severe climatic conditions. The high evaporation of water from the leaves of corn and kafir exceeds the intake by the roots; and, as a consequence, the water content is lowered to such an extent as to interfere with the vital processes of the protoplasm. The rise in temperature of the leaves due to the decreased transpiration may also be a factor in lowering the photosynthetic power of these plants. The dry-matter curves in figures 1, 7, 8, 9, 10, which represent the results for July 28 and August 11, 1914, and for the four experiments in 1916, show the marked increase in dry matter in the leaves of milo in comparison to the leaves of corn and kafir.

SUMMARY

The variation of the water and dry matter in the leaves of corn and the sorghums was determined by nine experiments in 1914, two in 1915, and four in 1916. These experiments were conducted with plants of Pride of Saline corn, Blackhull kafir, and Dwarf milo which were grown in the field, either in a series of plots or in alternate rows on the same plot. Four of the experiments in 1914 extended only through the daylight hours, but all the other experiments ranged in length from 24 to 48 hours. In these experiments the water and dry matter in the leaves were determined every two hours during 22 days and 10 nights for corn and milo and during 18 days and 10 nights for kafir.

The amount of water and dry matter in the leaves of a given variety of plant was obtained for any 2-hour period from 30 leaf samples, each with an area of 1 square centimeter. A single leaf on each of 30 representative plants furnished all the samples for an experiment extending over

any desired length of time. From the results thus obtained, the amount of water and dry matter for each square meter of leaf, the percentage of water on a wet basis, and the percentage of water on a dry basis were calculated.

The amount of water in the leaves of milo was found to be much lower at all times of the day and night than that of either corn or kafir leaves at a like stage of development, while the average water content of the corn and kafir leaves at the same age was practically the same. The water content of the leaves of corn, kafir, and milo averaged 118.5, 120.0, and 107.0 gm., respectively, for each square meter of leaf during the day periods and, taken in the same order, 127.9, 132.7, and 115.5 gm. for the night periods. The average variation per square meter of leaf between the water content of the leaves during the day and night was 9.4 gm. for corn, 12.7 gm. for kafir, and 8.5 gm. for milo. The average variation between the maximum and minimum water content of the leaves from 7 a. m. to 7 p. m. was 13.8, 8.4, and 7.8 gm. for each square meter of leaf respectively for corn, kafir, and milo, while the average range between the maximum water content of the leaves during the night and the minimum amount during the day was 23.8 gm. for corn, 25.9 gm. for kafir, and 21.7 gm. for milo

During the 22 days the evaporation as measured by a Livingston porous-cup atmometer reached a maximum 18 times between 2 and 3 p. m. and 4 times between 3 and 5 p. m. In two-thirds of the observations for corn and milo and in nine-tenths of the observations for kafir the minimum water content of the leaves under the conditions of these experiments occurred from two to four hours earlier than did the maximum evaporation as measured by the porous-cup atmometers. For the rest of the observations the minimum amount of leaf water occurred at the time of maximum evaporation.

The average variation between the maximum and minimum percentage of water in the leaves on a wet basis during the day from 7 a. m. to 7 p. m. was 3.5 for corn, 3.2 for kafir, and 4.5 for milo. On the same basis the average variation between the minimum percentage of water during the day and the maximum percentage during the night was 5.4, 5.9, and 6.0, respectively, for corn, kafir, and milo. The average difference between the minimum and maximum percentage of water on a dry basis during the day from 7 a. m. to 7 p. m. was 39.5 for corn, 31.1 for kafir, and 35.9 for milo. The average range between the maximum and minimum water content on this basis during the night from 7 p. m. to 7 a. m. was 37.5, 47.5, and 40.0, respectively, for corn, kafir, and milo, while the average range between the minimum percentage of water on this basis during the day and the maximum percentage at night was 67.8 for corn, 67.2 for kafir, and 51.2 for milo.

The dry weight of a given area of milo leaf was always found to be greater than an equal area of either corn or kafir leaves at the same stage of development. The average dry weight of a square meter of leaf for all the observations made was 48.2 gm. for corn, 52.5 gm. for kafir, and 56.2 gm. for milo. The average difference between the minimum and maximum amount of dry matter in the leaves for each square meter of leaf from 7 a. m. to 7 p. m. was 4, 4.8, and 8.0 gm., respectively, for corn, kafir, and milo. The increase in dry matter began at daybreak and the maximum amount of dry matter in the leaves occurred in most cases between 2 and 5 p. m. The rate of increase of the dry matter in the leaves during the portion of the day when the climatic conditions were severe was much higher for milo than for either corn or kafir.

The results indicate that under the conditions of these experiments the sorghums and, more particularly, milo can absorb water from the soil and transport it to the leaves more rapidly in proportion to the loss of water from the plant than can corn. As a result of this ability, the sorghums can produce more dry matter for each unit of leaf area under severe climatic conditions than the corn plant.

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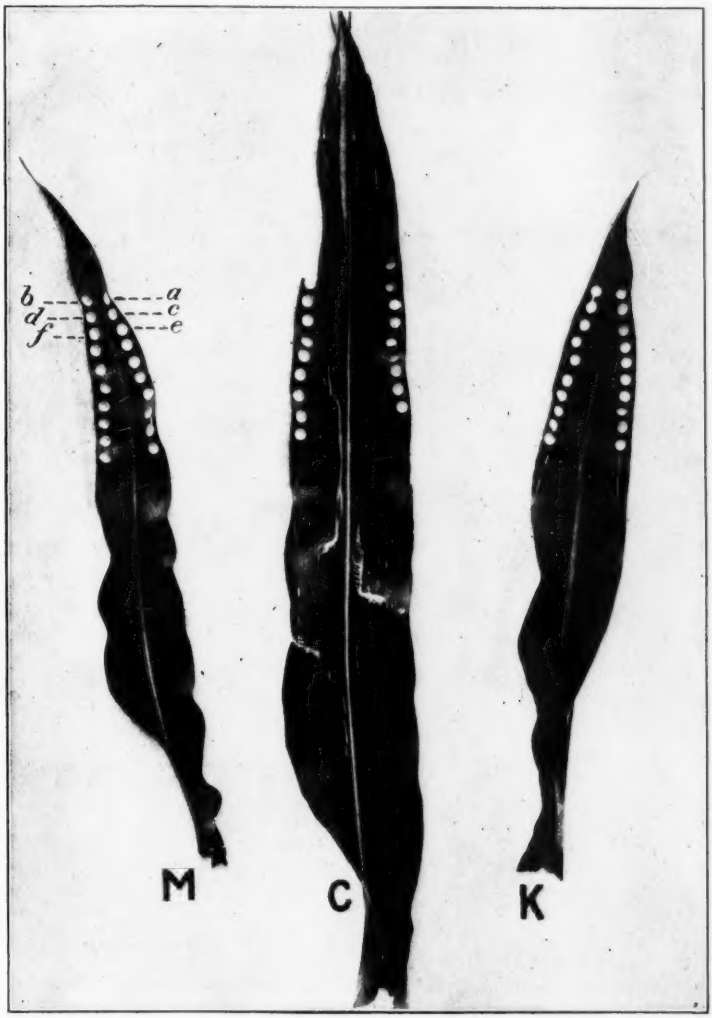
PLATE 3

Milo (*M*), corn (*C*), and kafir (*K*) leaves, illustrating the method used for obtaining the leaf samples for the determination of the water and dry matter.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A NEGLECTED FACTOR IN THE USE OF NICOTINE SULPHATE AS A SPRAY[1]

By WILLIAM MOORE, *Head of Section of Research in Economic Zoology*, and SAMUEL A. GRAHAM, *Assistant in Entomology, Minnesota Agricultural Experiment Station*

The attention of the authors was directed recently to a case of nicotine poisoning resulting from the use of greenhouse lettuce (*Lactuca sativa*). Thinking this an isolated case due to some florist's cutting his lettuce near the time of spraying with a tobacco extract, they took no further notice of this case. About a week later an entire family of nine, after eating leaf lettuce, became ill, showing distinct symptoms of nicotine poisoning. The lettuce was traced to the florist who had grown it, and further inquiry showed that his lettuce had been responsible for both cases of poisoning.

A few heads of this lettuce, crushed and distilled under alkaline conditions, gave a distillate with a distinct odor of nicotine.[2] The distillate gave characteristic reactions of nicotine when treated with mercuric chlorid, with a solution of iodin in iodid of potassium, and with a solution of mercuric and potassium iodid.

This test was carried out 12 days after the florist had sprayed his plants with a well-known commercial tobacco extract, containing 40 per cent of nicotine sulphate, using it, according to his statement, at the rate of 1 teaspoonful to 1 gallon of water. Other growers in the vicinity have used commercial tobacco extracts containing 40 per cent of free nicotine for years, even selling lettuce the day after spraying without causing any illness to the consumers. The question arose as to why the spray containing nicotine sulphate remained on the plants for 12 days, while similar sprays containing free nicotine quickly disappeared.

A COMPARISON OF NICOTINE AND NICOTINE SULPHATE

Nicotine is volatile, in fact very volatile, when one considers that its boiling point is 250° C. When sprays containing free nicotine are used, the nicotine quickly evaporates from the plant, leaving no trace when tested chemically the day after the spraying, even where used at the rate of 1 part to 100 parts of water. Fumigation with tobacco papers containing free nicotine left no trace of nicotine on lettuce leaves the morning after fumigation, even before the plants were sprinkled. Commercial

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[2] The authors wish to express their thanks to Dr. R. A. Gortner and Mr. J. J. Willaman for assistance in the chemical analysis given in this paper.

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tobacco extracts containing free nicotine are stated by the manufacturers to be for indoor use. On the other hand, commercial extracts containing nicotine sulphate are for outdoor use, the reason given by one manufacturer being that "sulphate of nicotine does not evaporate as quickly as free nicotine." McIndoo [1] claims that nicotine sulphate kills insects by its vapor in the same manner as nicotine. He mentions the death of insects from the odor and also the vapor of nicotine sulphate.

The first point in the investigation was to determine the volatility of nicotine sulphate. Pure nicotine was treated with concentrated sulphuric acid, and this mixture was then heated over a steam radiator for 15 hours to evaporate any free nicotine which might be present. The compound thus obtained was a dark-brown, sirupy mass with no odor. Later this was found to contain a number of crystals.

This compound was first tested upon house flies. One-liter Florence flasks were used as fumigation chambers. The flies were introduced into the flask and the neck closed with wire netting to prevent their gaining access to the nicotine sulphate, which was placed on a piece of filter paper suspended from the stopper. The stopper was rubber, covered with lead foil to prevent any absorption of vapor. Pure nicotine under such conditions will kill house flies within three hours, but the nicotine sulphate failed to kill them within the time a house fly will remain alive in such confinement. Commercial 40 per cent nicotine sulphate killed the flies in from three to six hours. In order to test these compounds further, the common croton bug (*Blatella germanica*) was used, as it will live in such confinement for a long time. Pure nicotine killed these insects in 3½ days, while those in the flasks containing commercial 40 per cent nicotine sulphate and pure nicotine sulphate were alive and active 10 days later.

Allen [2] states that on treating a solution of nicotine sulphate with an alkali the sulphuric acid will act just as if it were uncombined. The addition of soap to the nicotine sulphate in sufficient quantities to render it alkaline would therefore free the nicotine. The nicotine sulphate in one flask was rendered alkaline with soap, and it was then found that cockroaches in this flask died in the same length of time as those treated with pure nicotine. From these results it would appear that nicotine sulphate was nonvolatile. To test this point further, an attempt was made to distill the pure nicotine sulphate with steam. The result of this test was negative. On rendering the nicotine sulphate alkaline and again distilling with steam, the nicotine passed over in abundance. The distillation of commercial 40 per cent nicotine sulphate with steam showed that these preparations contain from 1 to 2 per cent of free nicotine.

[1] McINDOO, N. E. EFFECTS OF NICOTINE AS AN INSECTICIDE. *In* Jour. Agr. Research, v. 7, no. 3, p. 89–122, 3 pl. 1916. Literature cited, p. 120–122.

[2] ALLEN, A. H. COMMERCIAL ORGANIC ANALYSIS . . . v. 3, pt. 2, p. 183. Philadelphia, 1902.

These tests show that nicotine sulphate is relatively, if not absolutely, nonvolatile. The death of the flies in the experiment with commercial 40 per cent nicotine sulphate was due to the vapor from the small amount of free nicotine contained in these extracts. This quantity of free nicotine is apparently not sufficient to kill the croton bug.

McIndoo [1] apparently was working with commercial nicotine sulphate, and the odor and vapor of nicotine sulphate that he speaks of is really the odor and vapor of the free nicotine contained in these commercial extracts. If the death of the insects when sprayed with tobacco extracts is due entirely to the penetration of the vapor of the nicotine into the body of the insect, as claimed by McIndoo, then commercial tobacco extracts containing nicotine sulphate are really ineffective unless the nicotine is freed by rendering the solution alkaline. A small quantity of commercial tobacco extract was heated for a short time to evaporate the free nicotine. This extract was then made into a spray, using 1 part to 100 parts of distilled water. Chrysanthemums were thoroughly sprayed with this solution, killing about 40 to 50 per cent of the chrysanthemum aphids (*Macrosiphum sanborni*) infesting the plants. A portion of this solution was then rendered alkaline with sodium carbonate and used to spray other chrysanthemums. The alkaline solution killed 100 per cent of the aphids. This experiment was repeated, using pure nicotine sulphate and snapdragons (*Antirrhinum* spp.) infested with aphids (*Myzus persicae*). The solution of nicotine sulphate in distilled water killed less than 1 per cent of the aphids, probably only those knocked off the plant in spraying. Later, after the plants had been watered with tap water, a number (probably between 20 and 40 per cent) of the aphids on these plants died. This water was alkaline and apparently set free some of the nicotine, as a distinct odor of nicotine was noticed. The same solution of pure nicotine sulphate was rendered alkaline with sodium carbonate, to free the nicotine, and used on the snapdragons, when 100 per cent of the aphids were destroyed.

By titrating spray solutions containing commercial 40 per cent nicotine sulphate at the rate of 1 part to 1,000 parts of water it was found that the tap water at this Station would decompose about one-half of the nicotine sulphate contained in the solution. The addition of soap at the rate of 1 pound to 100 gallons of water broke down the rest of the nicotine sulphate. These results, however, will vary according to the alkalinity of the water, the amount of alkali in the soap, and the brand of commercial nicotine sulphate used.

The above facts probably explain the different results obtained in the use of tobacco extracts, and also why soap greatly increases the efficiency of sprays containing nicotine sulphate. Inasmuch as the vapor of nicotine is the principal cause of the death of insects in spraying with tobacco

[1] McIndoo, N. E. Op. cit.

extracts, the maximum efficiency of those containing nicotine sulphate can only be obtained by insuring that the spray gives at the time it is used an alkaline reaction. This may be obtained by the use of hard water, the addition of soap, or in some cases by the addition of a sufficient amount of sodium carbonate or lime water to produce an alkaline reaction.

The fact that nicotine sulphate is nonvolatile explains the cases of poisoning from eating lettuce sprayed with tobacco extracts containing this material. The only chance of removing nicotine sulphate from the lettuce leaves would be by dissolving it off in the water used in sprinkling. After sprinkling, the lettuce leaves are covered with drops of water in which the nicotine sulphate is held in solution. When these drops evaporate, there is a possibility of the nicotine being absorbed into the tissues of the leaf. This possibility is shown by the fact that, after several thorough sprinklings of the lettuce in the greenhouse, the plants will still show by chemical analysis slight traces of nicotine. In the experiments cited in this paper a slight burning of the foliage resulted from the use of nicotine sulphate, but not with free nicotine.

SUMMARY

(1) Nicotine sulphate is nonvolatile.

(2) Alkalies contained in hard water and soap set free the nicotine contained in nicotine-sulphate sprays.

(3) In order to obtain the maximum efficiency of tobacco extracts containing nicotine sulphates, they should be rendered alkaline before using.

(4) Commercial tobacco extracts containing nicotine sulphate should not be used in the greenhouse, at least not on plants which are later to be used for food.

(5) Tobacco extracts or tobacco papers containing free nicotine may safely be used in the greenhouse on plants such as lettuce, without endangering the lives of the consumers.

(6) Food plants such as lettuce sprayed with tobacco extracts containing free nicotine should not be cut for the market until the day after spraying. If the temperature of the house is low, a longer period should be given the nicotine to evaporate from the leaves.

A NEW DISEASE OF WHEAT

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The appearance in our Middle West of a new disease of wheat (*Triticum* spp.) is a matter of much concern. It is yet too early to map its distribution, but it has appeared in parts of Indiana, Arkansas, Kansas, Oklahoma, and Texas, and is believed to be present in other States.

I have been aware of the existence of this disease since 1902, having that year received a few diseased wheat spikelets from Indiana (courtesy of Dr. J. C. Arthur) with the statement that the inclosed might be of interest to me. It was then identified as probably a bacterial disease, but was not supposed to be one of any great importance. Since that year I heard nothing more concerning it until 1915, when abundant material was received in June from Kansas (courtesy of Mr. Leo E. Melchers), and again from Indiana (courtesy of Dr. H. B. Humphrey, of Cereal Investigations, Bureau of Plant Industry).

This year (1917), owing to the great slump in the yield of winter wheats in our Middle West (estimated at 150,000,000 bushels, and generally ascribed to winter-killing), I suspected that a part of the loss might be due to this new disease, and have sent three men into Texas, Oklahoma, Kansas, Arkansas, Missouri, and neighboring States to make an exploration. From each of these men I have received hard wheats showing the disease.

From the fact that it occurred in Indiana 15 years ago, it seems probable that this disease has existed in our wheat fields for many years unrecognized, either altogether overlooked or, what is more likely, confused with other wheat diseases. First, in 1915, probably under specially favorable weather conditions, it developed to such an extent as to attract general attention and frighten many farmers, especially in Kansas.

From the little we yet know it is not possible to predict its future course nor to pronounce positively as to its cause, although from the number of bacteria present in the spots, bacteria which are sometimes so abundant as to ooze to the surface in honey-like small drops, drying as crusts, and from the fact that the poured plates this year have yielded the same organism as in 1915, I believe it to be of bacterial origin. Should it increase, or even continue to prevail as extensively as in 1915 and this year, it will have to be reckoned with as a very serious disease of wheat, not as destructive as the rusts but more destructive than the

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smuts and very likely more difficult to control. On the contrary, if its recent prevalence has been due to very exceptional meteorological factors, such as the warm weather in May and June of 1915 associated with frequent rains or heavy dews, then we may expect it to be much less prevalent in years when these conditions do not prevail. I am inclined to take a serious view of the situation because the disease attacks not only the leaves, glumes, awns, rachis, and stalk of the wheat plant, thus sapping the vigor of the whole plant, but sometimes also the kernel itself, thereby suggesting (as already proved for maize attacked by *Bacterium stewarti*) that it is carried over from year to year on the seed.

A careful study of the disease is under way in the Laboratory of Plant Pathology to determine the biology of the parasite and whether it is actually transmitted from the seed to the young plant and so again to the seed, as I suspect. I have also entered into cooperation with the Kansas and the Wisconsin Experiment Stations for the further study of this disease. This study will require considerable time, and it is desired here only to call attention to some of the conspicuous signs of the disease and to ask for samples of it from Station workers and others in all parts of the United States, together with reports concerning its prevalence, that we may know as speedily as possible its distribution and the extent of the danger.

The principal signs on the ripening grain are as follows:

CHAFF.—In late stages, as the wheat approaches maturity, black, longitudinal, parallel, more or less sunken stripes occur which, as a rule, are more numerous and conspicuous on the upper parts, where they often fuse, but which also often extend to the base of the glume. Internally, in the parts corresponding to the stripes, the glumes are black- or brown-spotted and swarming with bacteria, but sometimes, at least, fungi are also present. In bearded wheat the beards are often attacked and browned, at least in their basal parts.

RACHIS AND STALK.—In late stages these are both conspicuously brown- or black-striped.

LEAVES.—In 1915 I did not see the disease on the leaves, not many leaves having been sent me, but from what I have seen this year I know that they also are attacked (Pl. 4, fig. 3).

KERNELS.—When the disease is serious, the kernels are badly shriveled, and, in some cases at least, they show small cavities occupied by bacteria.

WHOLE PLANT.—The result of this disease is a dwarfing of the spike and a very marked shriveling of the kernels, with corresponding reduction of the yield.

Plate 4, figures 1 and 2, from Kansas wheat (crop of 1915) shows the black striping on the glumes and rachis, and Plate 8 shows the common shriveling of the kernels.

Plate 5 is of wheat from Fort Worth, Tex. (crop of 1917).

Plate 6, figure 2, and Plate 7, from Arkansas wheat (crop of 1917) show black glumes, twisted awns, and bacterial ooze from the rachis and from the stems.

Based on what I have seen, two tentative pieces of advice may be offered:

(1) Use, this autumn, seed wheat derived only from fields known to have been free from the disease.

(2) Avoid the use of manure from animals fed on or bedded on diseased straw. Such manure should be used only on fields not intended for wheat or other grains. Animals pastured on diseased wheat stubble should not have the range of fields designed for the next crop of wheat.

It is hoped that by the middle of August of this year sufficient data may be in hand to make a definite statement as to the cause of the disease, the localities where it occurs, the approximate losses due to it, its method of distribution—that is, whether on the seed or not—and the best means for holding it in check, if any can be found.

PLATE 4

1, 2.—Spikes magnified to show more distinctly the dark blotches and stripes which are signs of the disease. Kansas, 1915. Bacteria present.

3.—Outer surface of a leaf sheath showing black spots and stripes occupied by bacteria. No. 153. Farmington, Ark., 1917.

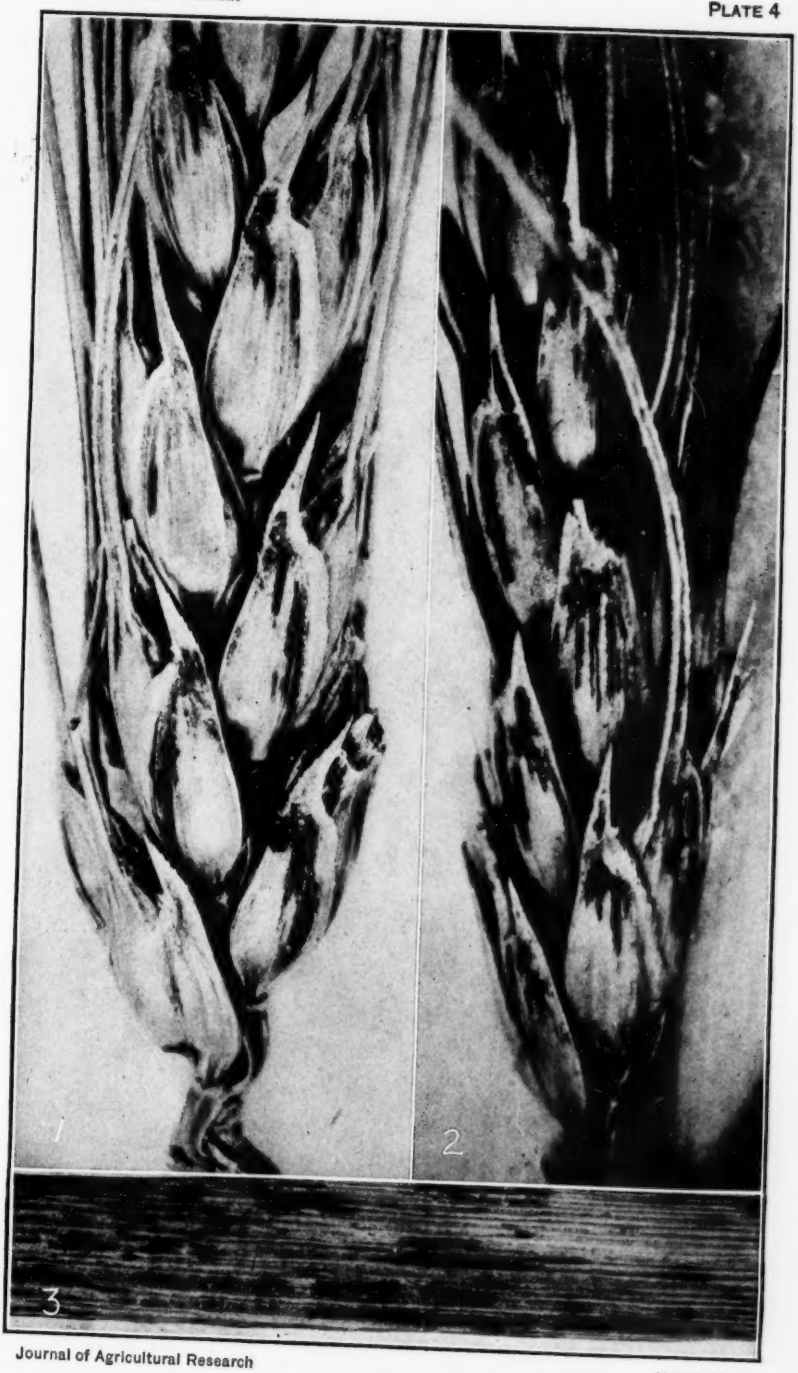
1
2
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PLATE 5

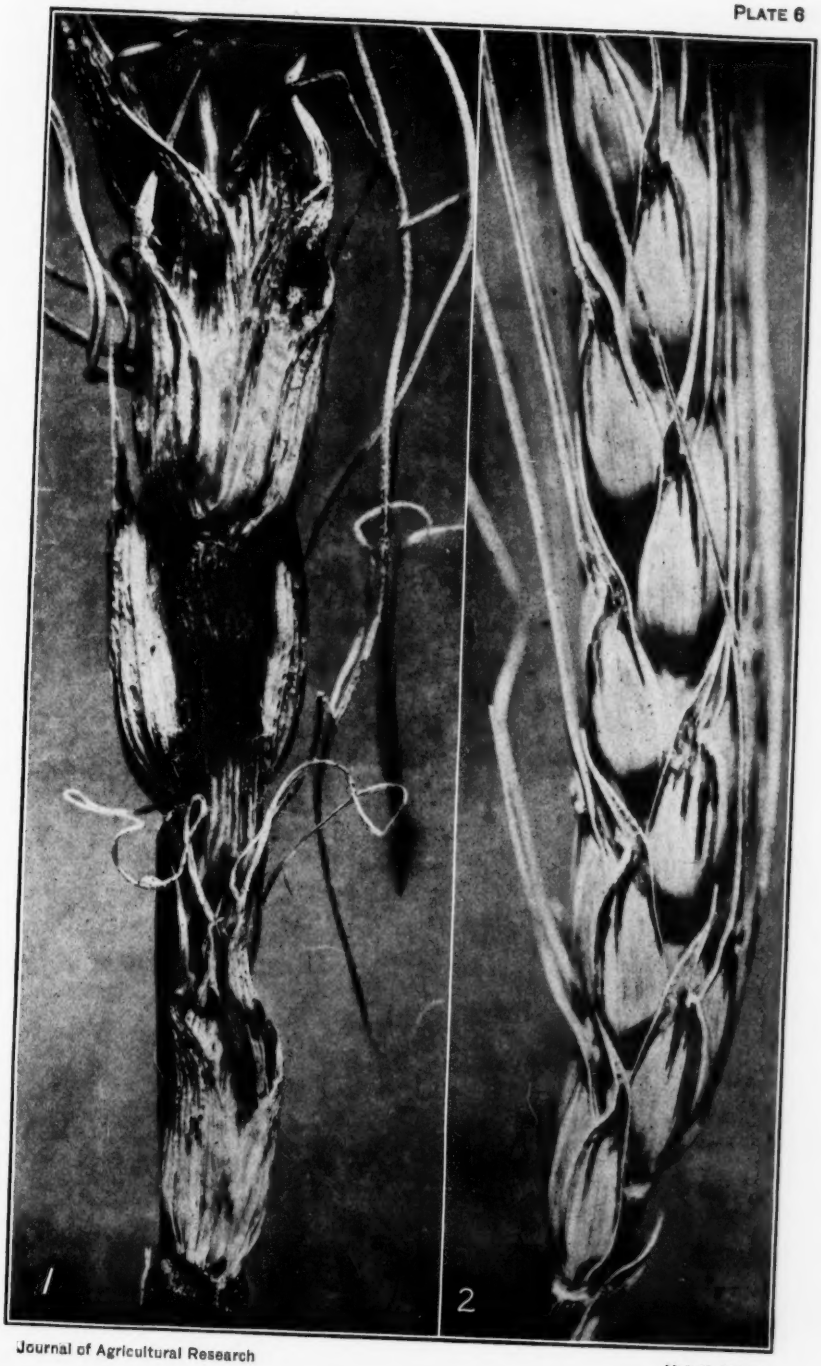
Spikes magnified to show black stripes on glumes and awns. Fort Worth, Tex., 1917. No. 97. Bacteria present.

PLATE 6

1.—Black stripes on glumes, awns, and rachis. Rhome, Tex., 1917. No. 171. Bacteria present.

2.—Spikelets aborted and blackened, awns twisted, rachis badly diseased (blackened or water-soaked in appearance and oozing bacteria). Farmington, Ark., 1917. No. 153.

PLATE 6



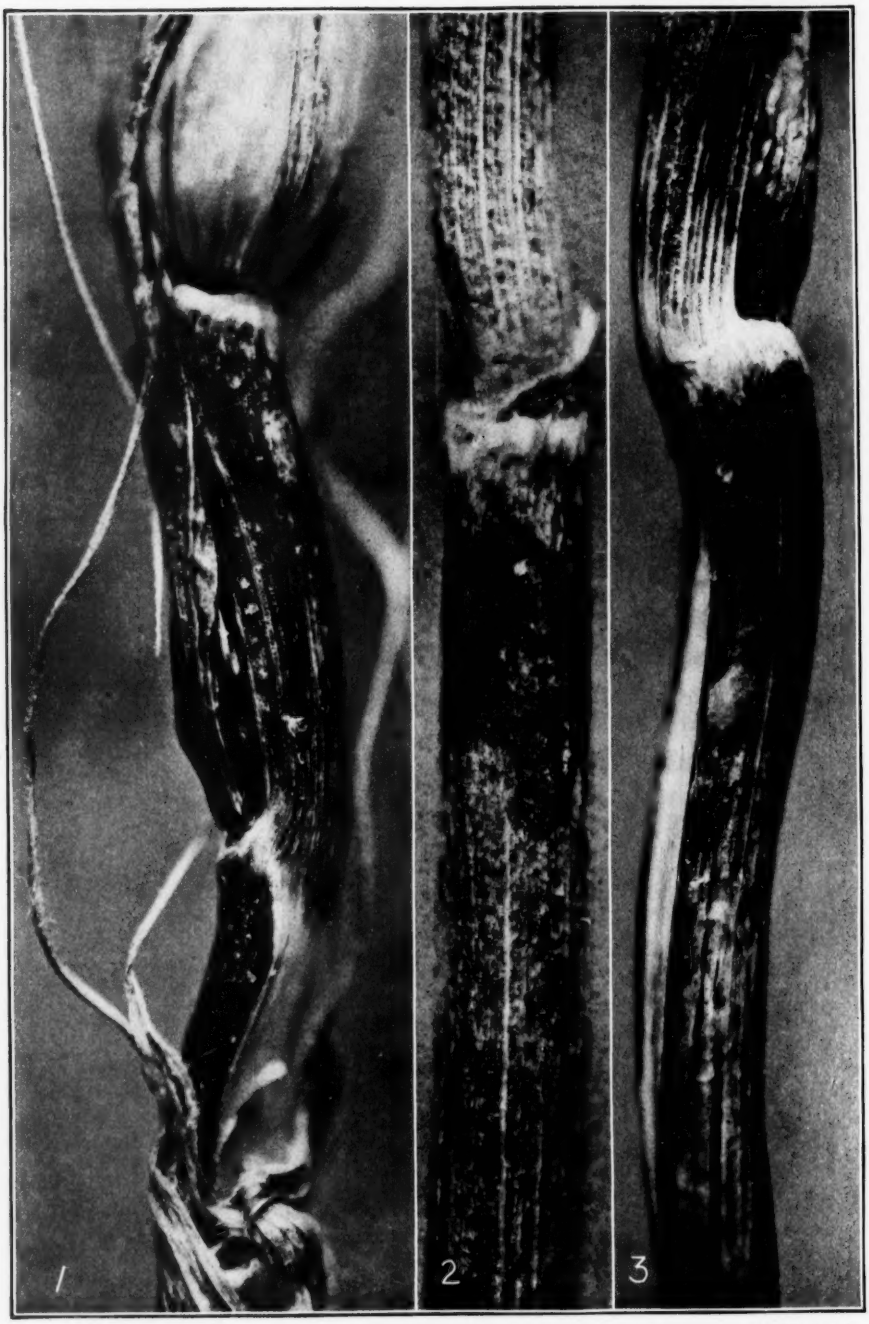

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PLATE 7

1.—Rachis black and oozing honey-yellow bacterial slime which dries as pale yellowish or whitish crusts. The awn at the left is also black in spots. Farmington, Ark., 1917. No. 155.

2, 3.—Same disease on upper part of culm showing as dark spots or stripes oozing pale-yellow masses of bacteria. Farmington, Ark., 1917. No. 153.

PLATE 8

Shriveled kernels from a single head of wheat like those shown on Plate 4. Not one berry is plump, and many are badly shriveled. Kansas, 1915. Enlarged, × 6½.
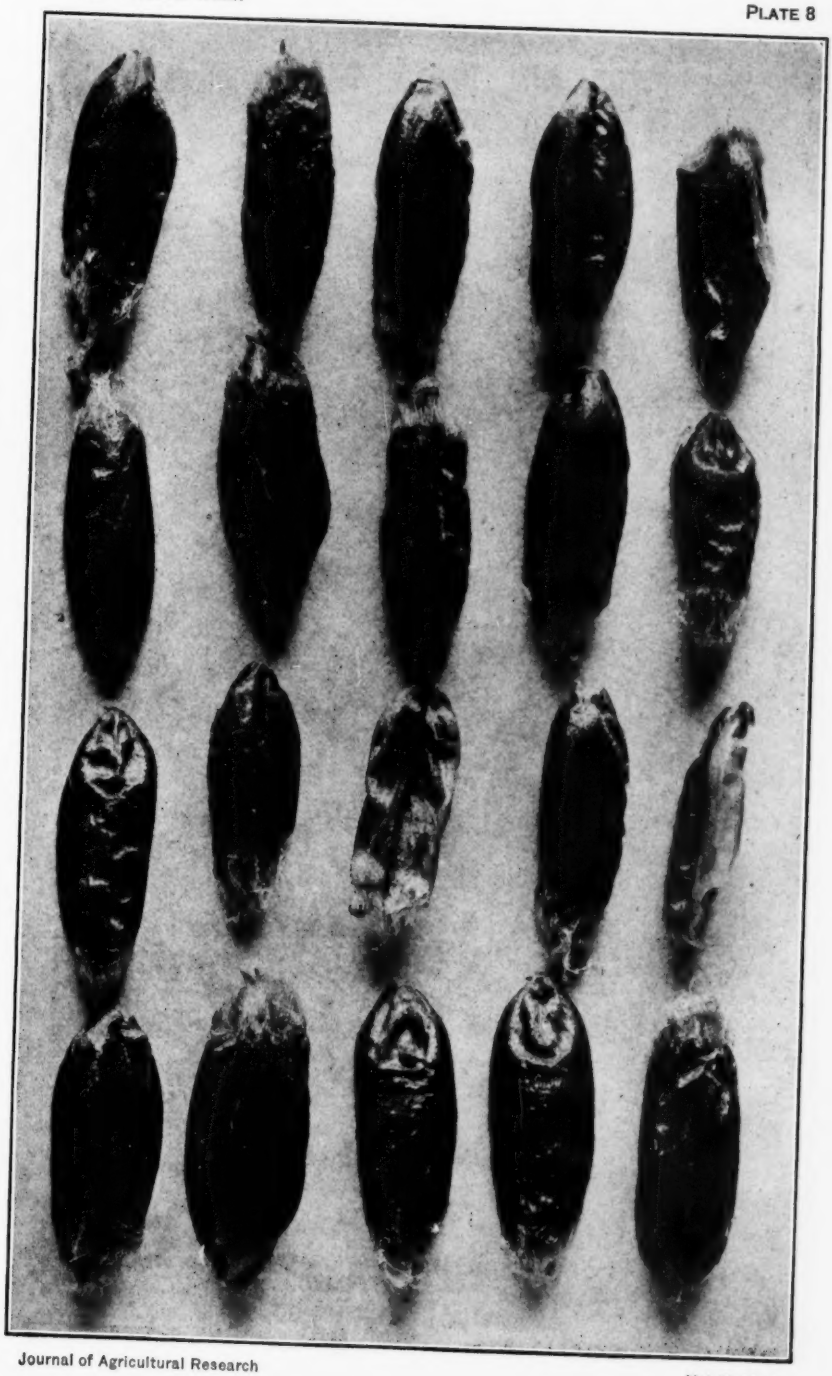
PLATE 8